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DURING THE CRUISES OF

THE DANISH RESEARCH STEAMER "THOR" IN THE SUMMER 1903

BY

J. N. NIELSEN

KØBENHAVN
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Material of Observation.

PART of the material of observation, on which this paper is based, has been published in "Bulletin des résultats acquis pendant les courses périodiques, Mai et Aout 1903"; this concerns the hydrographical stations (1—19 and neighbouring supplementary stations 4 A, 4 B, 4 C, 4 D, 4 E, 4 F, 5 A, 7 A, 7 B, and 10 A) in the seas between the Faroe islands and Iceland. Besides at these stations, researches were made at some stations during the fishery cruise of the "Thor" round Iceland. The material of observation from these stations (20—54) is noted in the following Table I. m means the depth measured in meters, $t°$ the corrected temperature (Celsius), $S°/_{00}$ the salinity in pro mille, and σ_t is an expression for the specific gravity s_t, calculated by temperature and salinity, which is not corrected for pressure. $\sigma_t = 1000\ (s_t - 1)$.

For the above mentioned stations 1—19 and the neighbouring supplementary stations the results of the examined samples of the surface water have been published in the "Bulletin des résultats etc. Mai et Aout 1903", for the stations 20—54 they are noted in Table I; the rest of the samples of the surface water, which were taken and examined during the cruise, and of which part are the basis of the surface maps for May and August, are noted in Table II.

The sections are drawn according to the scale used for sections from these seas in "Bulletin des résultats etc. Aout 1903", that is: 1^{mm} represents 2 kilometers in horizontal direction, and 10 meters in vertical direction; only in section XIV the double scale is applied in vertical direction.

Table I.

m	$t°$	$S°/_{00}$	σ_t
Station **20** 1903 V 24 65°43′ N Lat. 12°30′ W Long. 210 m.			
0	1·40	34·67	27·77
20	0·96	65	78
50	89	67	81
100	81	67	81
150	32	70	87
200	18	74	91
Station **21** 1903 V 24 65°57′ N Lat. 11°31′ W Long. 264 m.			
0	0·62	34·52	27·70
25	27	52	72
50	17	54	75
75	18	60	79
100	23	65	83
150	0·40	34·72	27·88
250	26	72	89
Station **22** 1903 V 25 66°15′ N Lat. 10°44′ W Long. c. 1400 m.			
0	0·95	34·66	27·79
25	67	65	80
50	57	67	83
75	54	67	83
100	16	70	88
150	—0·13	78	96
200	02	85	28·00
300	0·12	92	05
400	13	92	05
500	—0·07	94	08
600	26	94	09
700	—0·43	34·94	28·10
1400	90	94	12
Station **23** 1903 V 25 66°08′ N Lat. 11°13′ W Long. 890 m.			
0	1·01	34·58	27·73
10	0·73	—	—
25	56	—	—
50	29	58	77
100	20	70	88
150	15	76	92
175	12	76	92
200	—0·41	76	95
250	32	84	28·01
275	0·10	87	01
300	21	90	04
350	34	90	03
500	—0·06	34·90	28·05
850	58	88	06
Station **24** 1903 V 29 64°57′ N Lat. 13°28′5 W Long. 120 m.			
0	1·83	34·52	27·62
10	79	52	62
15	72	52	63
20	58	58	69
30	59	58	69
50	50	58	69
115	48	58	69
Station **25** 1903 V 30 64°25′ N Lat. 14°11′ W Long. 91 m.			
0	4·11	34·61	27·49
15	3·90	65	53

m	$t°$	$S‰$	σ_t
30	4·37	34·72	27·55
50	79	79	56
90	5·05	83	56

Station **26** 1903 V 31
63°15′ N Lat. 14°20′ W Long.
15—1700 m.

0	8·09	35·24	27·46
50	7·91	23	49
100	74	23	51
200	66	23	52
300	56	22	53
400	49	21	54
500	38	21	55
650	16	21	59
800	6·86	21	63
1000	19	17	69
1500	3·16	—	—
"	10	03	82

Station **27** 1903 V 31
63°41′ N Lat. 14°30′ W Long.
185 m.

0	7·81	35·19	27·47
20	81	19	47
50	71	18	48
75	38	19	53
100	35	19	54
150	20	19	56
185	16	19	57

Station **28** 1903 V 31
64°00′ N Lat. 14°40′ W Long.
160 m.

0	7·75	35·16	27·45
10	87	18	46
25	77	18	47
50	59	19	50
75	40	19	53
100	28	20	56
150	24	17	54

Station **29** 1903 VI 10
64°10′ N Lat. 23°22′ W Long.
105 m.

0	7·63	35·075	27·40
10	44	07	43
25	20	08	47
50	05	08	49
75	6·80	12	56
100	79	14	58

m	$t°$	$S‰$	σ_t

Station **30** 1903 VI 11
64°10′ N Lat. 24°22′ W Long.
295 m.

0	7·20	35·14	27·52
20	21	14	52
50	11	14	53
100	6·73	16	62
200	51	14	62
290	5·78	12	71

Station **31** 1903 VI 11
64°10′ N Lat. 25°26′ W Long.
248 m.

0	7·17	35·12	27·51
25	14	12	51
50	01	14	55
75	6·79	16	59
100	52	14	61
200	09	14	67
245	5·99	12	67

Station **32** 1903 VI 11
64°13′5 N Lat. 27°30′ W Long.
817 m.

0	7·70	35·14	27·45
25	45	16	49
50	41	16	50
75	18	16	54
100	6·86	16	58
200	53	13	60
300	42	11	60
400	28	10	62
500	06	10	65
600	5·96	10	66
700	87	09	66
810	48	07	69

Station **33** 1903 VI 12
64°13′·5 N Lat. 28°31′ W Long.
1600 m. no bottom.

0	7·66	35·14	27·45
25	62	15	47
50	40	16	50
100	01	14	55
200	6·63	10	57
300	48	10	59
400	30	08	60
600	5·69	04	64
800	01	02	72
1200	4·13	01	81
1600	3·64	00	85

m	$t°$	$S‰$	σ_t

Station **34** 1903 VI 12
65°28′ N Lat. 28°31′ W Long.
c. 1300 m.

0	7·11	34·97	27·41
100	6·54	35·12	59
200	37	09	60
400	11	07	61
800	4·67	34·98	72
1200	3·87	96	78

Station **35** 1903 VI 12
65°33′ N Lat. 28°43′ W Long.

0	3·51	33·13	26·37
4	4·17	—	—
5	—	33·17	—
6	5·77	—	—
7·5	01	24	40
10	6·42	34·70	27·29
20	60	88	40
30	81	35·03	49
40	84	10	54
50	71	11	57
75	67	11	57
100	58	11	58

Station **36** 1903 VI 13
65°45′ N Lat. 27°03′ W Long.
510 m.

0	2·40	33·04	26·41
10	6·82	35·06	27·51
30	81	—	—
50	81	08	53
75	65	—	—
100	46	08	57
200	30	10	61
400	5·71	07	67
500	30	07	71

Station **37** 1903 VI 13
65°38′ N Lat. 25°38′ W Long:
225 m.

0	3·20	33·46	26·66
5	52	46	63
10	5·63	34·43	27·17
20	6·02	81	43
30	6·11	90	48
50	17	35·01	56
75	07	07	62
100	5·80	04	63
150	55	04	66
220	32	03	69

m	$t°$	$S‰$	σ_t

Station **38** 1903 VI 13
66°08′ N Lat. 24°37′ W Long.
98 m.

0	2·29	32·84	26·25
10	47	88	26
12·5	3·25	—	—
15	4·83	34·33	27·28
18	5·48	—	—
20	40	34·96	61
22·5	49	—	—
25	4·83	97	70
30	77	97	71
50	76	—	—
75	72	35·01	74
95	72	01	74

Station **39** 1903 VI 14
66°18′ N Lat. 23°44′ W Long.
42 m.

0	5·30	34·83	27·52
20	33	—	—
40	34	83	52

Station **40** 1903 VI 16
66°33′ N Lat. 22°47′5 W Long.
91 m.

0	5·30	34·18	27 02
5	29	18	02
10	12	31	13
20	4·97	36	19
30	92	40	23
40	92	—	—
50	93	43	26
70	87	51	32
90	82	56	37

Station **41** 1903 VI 17
66°13′ N Lat. 20°29′ W Long.
62 m.

0	4·93	33·93	26·85
10	12	34·14	27·12
20	3·85	33	28
40	98	77	65
60	4·02	83	67

Station **42** 1903 VI 18
66°15′ N Lat. 18°58′ W Long.
65 m.

0	3·91	33·66	26·74
10	43	78	90
20	50	34·30	27·30
40	92	70	61
60	82	69	57

Station **43** 1903 VI 30
66°36′5 N Lat. 18°06′ W Long.
105 m.

m	$t°$	$S‰$	σ_t
0	3·98	33·84	26·89
10	55	91	99
20	00	34·29	27·34
30	2·59	27	36
50	56	51	55
63	3·01	60	58
75	21	61	59
104	2·73	56	58

Station **44** 1903 VII 2
66°19′ N Lat. 23°22′ W Long.
114 m.

m	$t°$	$S‰$	σ_t
0	6·72	34·34	26·94
10	84	49	27·06
15	62	78	33
20	5·94	79	42
40	92	92	53
50	88	92	53
75	59	94	58
112	25	35·01	68

Station **45** 1903 VII 3
65°29′5 N Lat. 24°34′5 W Long.
43 m.

m	$t°$	$S‰$	σ_t
0	7·95	34·31	26·76
10	83	36	82
15	67	45	91
25	48	54	27·01
40	43	61	08

Station **46** 1903 VII 4
65°11′ N Lat. 24°18′ W Long.
76 m.

m	$t°$	$S‰$	σ_t
0	8·91	34·61	26·86
10	—	59	—
25	32	78	27·07
40	7·51	34·90	27·29
50	6·94	92	39
75	63	88	40

Station **47** 1903 VII 4
64°39′ N Lat. 23°40′ W Long.
91 m.

m	$t°$	$S‰$	σ_t
0	10·01	34·18	26·34
10	9·78	22	40
13	63	—	—
17	8·46	63	94
25	7·85	69	27·07
50	70	83	20
75	26	35·01	40
90	13	07	47

Station **48** 1903 VII 4
64°23′ N Lat. 22°52′ W Long.
88 m.

m	$t°$	$S‰$	σ_t
0	10·30	34·05	26·17
10	31	05	17
16	9·45	25	48
25	8·68	67	93
35	09	87	27·18
50	7·71	92	27
85	31	35·07	45

Station **49** 1903 VII 11
63°40′ N Lat. 22°03′ W Long.
157 m.

m	$t°$	$S‰$	σ_t
0	9·86	33·87	26·12
10	30	34·58	76
20	8·75	88	27·08
30	31	35·05	28
50	7·91	10	39
75	33	14	50
100	12	12	51
152	05	10	51

Station **50** 1903 VII 12
63°24′ N Lat. 20°02′ W Long.
155 m.

m	$t°$	$S‰$	σ_t
0	9·84	34·875	26·90
10	78	87	91
20	61	93	98
30	09	35·07	27·17
50	8·55	10	29
75	7·81	19	47
100	67	19	49
150	50	17	51

Station **51** 1903 VII 13
62°11′ N Lat. 19°36′ W Long.
1900 m. no bottom.

m	$t°$	$S‰$	σ_t
0	10·48	35·21	27·05
10	40	21	06
20	28	21	09
30	9·54	21	22
50	06	21	30
75	8·56	19	36
100	33	19	39
150	12	19	42
200	7·96	18	45
300	87	18	46
400	73	17	48
500	61	17	49
600	46	17	51
800	6·65	12	58
1000	5·28	07	71
1400	3·70	34·99	83
1900	2·85	35·03	94

Station **52** 1903 VII 14
62°35′ N Lat. 19°48′ W Long.
1390 m.

m	$t°$	$S‰$	σ_t
0	11·14	35·16	26·88
25	9·51	16	27·17
50	8·47	35·16	27·35
75	16	17	41
100	04	17	42
200	7·73	17	48
300	63	17	48
400	49	165	50
600	09	14	54
800	6·10	10	64
1000	4·98	07	75
1375	3·78	02	95

Station **53** 1903 VII 14
62°57′ N Lat. 19°58′ W Long.
955 m.

m	$t°$	$S‰$	σ_t
0	10·80	35·12	26·92
25	14	14	27·06
50	8·55	19	36
75	13	19	42
100	7·91	19	46
200	62	17	49
300	45	17	51
400	28	17	54
600	6·84	17	60
800	5·63	12	71
950	28	08	72

Station **54** 1903 VII 17
63°16′5 N Lat. 19°57′ W Long.
250 m.

m	$t°$	$S‰$	σ_t
0	11·70	34·99	26·66
25	10·06	35·12	27·05
50	8·73	14	29
75	11	—	—
100	7·92	21	48
150	70	—	—
200	61	—	—
240	48	21	54

Table II.

Time	N Lat.	W Long.	Surf. temp.	Surf. salin.
1903				
V 12	62°58′	8°00′	7·20	35·28
» »	47′	30′	60	21
» »	30′	9°07′	71	28
» »	25′	25′	20	28
» 13	27′	48′	70	25
» »	63°29′	13′	50	25
» »	64°01′	8°53′	40	—
» »	09′	49′	6·60	23
» »	21′	42′	3·30	34·88
» 14	20′	54′	50	87
» »	18′	9°01′	5·86	—
» »	13′	15′	6·50	35·16
» »	63°51′	10°18′	7·30	19
» »	30′	11°00′	6·98	17
» »	23′	18′	7·20	17
» 15	19′	45′	22	21
» »	28′	45′	6·45	17
» »	36′	45′	5·93	12
» »	43′	45′	6·10	14
» »	51′	45′	90	17
» »	59′	45′	7·13	21
» »	64°22′	45′	22	24
» »	46′	45′	1·18	34·85
» 16	58′	12°12′	18	70
» »	58′	13°11′	19	69
» 24	65°25′	35′	65	56
» »	27′	29′	65	65
» »	28′	23′	70	60
» »	30′	17′	62	56
» »	32′	11′	93	60
» »	33′	05′	2·16	45
» »	35′	12°58′	20	47
» »	37′	52′	1·72	56
» »	38′	46′	98	60
» »	40′	40′	36	65
» »	43′	30′	40	67
» »	50′	00′	0·71	52
» »	66°01′	11°20′	90	52
» »	05′	10°58′	50	42
» 25	12′	49′	48	69
» 31	63°30′	14°23′	8·19	—
» »	52′	35′	7·80	35·21
VI 1	64°16′	44′	70	16
» 2	61°31′	13°55′	8·84	30
» »	31′	14°57′	11	26
» 3	31′	16°00′	84	26
» »	31′	17°08′	67	25
» »	31′	18°40′	9·10	30
» »	62°00′	19°04′	8·49	19
» »	20′	04′	47	19
» »	40′	04′	39	19
» »	51′	05′	30	34·32
» 4	63°00′	05′	23	35·02
» »	08′	05′	11	33·64
» »	13′	05′	09	15
» »	17′	05′	08	34·23
» 10	64°10′	23°13′	7·72	92
» »	10′	57′	41	35·16
» »	10′	24°43′	29	16
» 11	10′	25°15′	10	13
» »	10′	40′	31	14
» »	13′	26°08′	34	—
» »	13′	30′	51	16

Time	N Lat.	W Long.	Surf. temp.	Surf. salin.
1903				
VI 11	64°13′	27°00′	7·81	35·12
» 12	13′	47′	71	16
» »	13′	28°10′	71	14
» »	40′	31′	77	14
» »	48′	31′	95	14
» »	56′	31′	60	10
» »	59′	31′	80	10
» »	65°04′	31′	70	10
» »	12′	31′	42	—
» »	20′	31′	39	07
» »	36′	10′	4·90	34·02
» »	42′	27°28′	6·50	76
» 13	30′	26°10′	4·95	00
» »	35′	25°45′	2·35	78
» »	50′	10′	6·46	65
» »	58′	24°48′	2·19	32·72
» »	66°11′	20′	65	—
VII 11	63°35′	22°32′	9·58	34·05
» »	37′	21°22′	10·05	32·61
» »	33·5	20°56′	9·88	33·40
» »	30′	35′	70	55
» 12	28′	14′	36	34·56
» »	26′	10′	68	90
» 14	05′	19°58′	11·30	—
» »	03′	58′	66	—
» »	05′	58′	15	—
» »	08′	58′	19	97
» 20	30′	15°42′	28	33·69
» »	38′	25′	10·76	34·96
» »	45′	10′	11·06	34
» »	53′	02′	10·68	47
» »	64°01′	14°49′	5·42	33·96
» »	18′	32′	6·91	86
» 26	65°30′	13°31′	5·03	03
» »	46′	14°09′	6·98	08
» »	47′	13°57′	7·00	28·96
VIII 4	64°58′	00′	5·42	34·24
» »	58′	12°16′	53	40
» »	58′	11°53′	6·27	52
» »	51′	45′	12	50
» 5	22′	45′	8·50	35·05
» »	00′	45′	7·57	34·78
» »	63°49′	45′	8·32	83
» »	33′	45′	33	79
» »	23′	45′	98	35·01
» 6	27′	12′	92	18
» »	33′	10°57′	74	08
» »	48′	23′	17	01
» »	53′	05′	93	09
» »	64°03′	9°49′	90	08
» 7	13′	07′	97	08
» »	22′	8°57′	10	34·87
» »	27′	40′	6·82	70
» »	48′	48′	37	69
» »	42′	9°02′	15	63
» 8	32′	13′	8·46	88
» »	18′	18′	77	35·05
» »	63°56′	18′	49	34·89
» »	42′	32′	38	85
» »	32′	50′	9·06	83
» »	20′	58′	40	35·08
» 9	03′	10°22′	26	01
» »	62°52′	32′	10·07	24

Time	N Lat.	W Long.	Surf. temp.	Surf. salin.
1903				
VIII 9	62°42′	10°42′	10·39	35·23
» 8	28′	35′	18	28
» »	23′	9°55′	60	26
» »	21′	8°55′	28	25
» »	19′	30′	32	28
» 13	61°42′	7°20′	9·41	19
» »	47′	55′	72	19
» 14	62°18′	9°43′	10·90	26
» »	25′	28′	49	25
» »	32′	11′	38	26
» »	50′	8°27′	00	07
» »	58′	10′	50	19
» »	63°08′	7°52′	78	34·90
» »	26′	31′	9·80	97
» »	36′	31′	10·03	35·12
» 15	64°05′	31′	8·32	34·76
» »	15′	12′	40	76
» »	18′	6°48′	56	76
» »	08′	27′	20	74
» »	63°57′	32′	90	—
» 16	43′	38′	9·96	35·21
» »	32′	42′	91	—
» »	23′	47′	96	08
» »	06′	52′	78	10
» »	62°47′	58′	15	19
» 18	20′	7°11′	40	19
» 19	25′	00′	30	16
» »	30′	6°40′	27	17
» »	44′	20′	37	26
» »	55′	20′	10·05	16
» 22	63°17′	20′	07	16
» »	44′	20′	8·62	34·96
» 23	58′	20′	7·90	70
» »	64°04′	20′	9·20	85
» »	19′	20′	38	99
» »	29′	20′	02	81
» »	39′	20′	8·26	73
» »	43′	5°58′	47	92
» »	43′	32′	9·10	35·07
» 24	43′	4°45′	80	34·83
» »	43′	20′	95	85
» »	33′	05′	54	85
» »	24′	23′	58	79
» »	14′	43′	66	88
» »	05′	50′	70	88
» »	63°58′	5°00′	79	88
» »	31′	30′	8·00	91
» »	17′	48′	9·50	35·12
» 25	07′	55′	06	07
» »	62°55′	6°02′	70	16
» »	47′	13′	74	—
» »	37′	20′	95	10
IX 10	61°17′	09′	46	19
» »	07′	5°35′	48	19
» »	60°56′	00′	74	08
» »	46′	4°26′	95	28
» »	36′	3°51′	10·85	35
» »	26′	18′	11·03	39
» »	15′	2°43′	00	03
» 11	05′	09′	10·49	21
» »	59°52′	1°22′	13	25
» »	60°00′	0°38′	11·00	28
» »	59°52′	0°03′	25	07

Apparatus and Methods.

Determinations of Salinity.

The salinities are generally determined by titration. In some cases — especially in isolated determinations of the salinity of the surface water in such cases where it was of interest to know it immediately — a set of hydrometers of Jena glass 59^{III} furnished by L. Steger, Kiel, have been used. Though the indications of the hydrometer were corrected by means of the salinities determined by titration, the error in the salinities determined by the hydrometer might amount to 0·2 ‰. The hydrometer determinations were generally undertaken in a glass which was placed in Cardanic suspension on an iron rod fixed to the table and the ceiling of the laboratory; in this way the pitching of the ship had not much influence; but on the other hand the shakings from the engine of the ship now play a greater part, and it is probably this circumstance to which the above mentioned great uncertainty is due.

In almost all titrations (when the salinity was above 30 ‰) a bulb burette, made by C. Richter, Berlin, and ordered by the Hydrographic Laboratory in Copenhagen, was used. The principle is the one well known from Knudsen's pipette, the upper mark being replaced by a stopcock by which the adjustment to the zeropoint is avoided, which, especially when the ship is pitching, gives considerable trouble, and besides in this way the error of adjustment is perfectly eliminated. It is a wellknown fact that the walls of a common burette are greased round the zeropoint by the stopcock grease which the solution carries along with it from the stopcock which is placed in the tube leading to the vessel containing the solution; in this layer of grease a great deal of the small particles swimming in the solution are deposited, and so we have a source of errors which may rise considerably if the burette is not cleaned frequently. In the burette with the stopcock above this source of errors is reduced to the least possible, when the burette is filled so that the surface is a little above the upper stopcock, and by the next filling the solution above the stopcock is driven into a test-glass placed under the upper, bent part of the burette.

Determinations of Temperature.

The determinations of temperature are undertaken with a thermometer placed in the water-bottle (Petterson-Nansen's insulated water-bottle). The thermometer was the common deep-sea thermometer, furnished by C. Richter, Berlin, enclosed in a glass mantle which had been tested with a pressure of 500 atm. It was divided in tenth degrees and tested at the "Physikalisch-technische Reichsanstalt" at Charlottenburg. When the determination of temperature from greater depths is in question some corrections must be applied to the temperature read after the hauling up. In great depths the water is subject to a very great pressure, and when a certain volume is blocked up in the water-bottle, and the latter is hauled up, the pressure in the water outside will gradually be reduced, and when the difference between the pressure inside and outside the water-bottle has reached a certain value, it will open a valve in the lid and a little of the water will stream out. As we consider the water-bottle being perfectly insulating this alteration of volume will be isentropic, and so the extension will effect a cooling of the water in the water-bottle, so that to the temperature read must be added a little amount which depends on the pressure and on the state of the water. Another source of error is the supply of heat during the hauling up. When the water-bottle, filled with cold bottom water, is hauled through warmer layers of water a supply of heat will take place partly by transmission, partly in consequence of the production of heat by friction. The influence of the transmission of heat may be determined, when we know the rate of warming of the water-bottle, when the outer conditions are known, while the influence of the friction can only be determined by experiments. The thermometer being enclosed in a glass mantle causes its indication to be almost independent of the pressure.

The correction of temperature for the alteration of pressure may be determined by Lord KELVIN's[1]) formula for the thermal effect of fluids by compression

$$d\theta = \frac{\theta e p}{I C_p \rho_0}$$

where θ is the absolute temperature ($\theta = 273 + t$, where t is the temperature in centigrade), e the extension for the warming of 1 degree from the existing temperature, p the pressure (measured in kilog. on the square meter), I the equivalent of heat (425 kilogram-metres), C_p the capacity for heat at constant pressure, and ρ_0 the weight in kilog. of a cubic meter of the fluid.

As to seawater the formula has not been subject to any trial, JOULE[2]), however, by experiments with distilled water, found the best accordance with the theory (the mean difference = 0·0002° C.), and so there can scarcely be any reason to doubt its validity for seawater. In the table below which indicates the correction C for a depth of 1000 meters, the extension is calculated according to MARTIN KNUDSEN's tables, while the product $C_p \rho_0$ according to FRIDTJOF NANSEN[3]) has been put = 960. The table holds good for water of the salinity of 35 ‰.

$t°$	C
−1	$+ 3 \times 10^{-2}$
0	3
1	4
2	5
3	5
4	6
5	7
6	8
7	9
8	10

In a great number of cases the water-bottle thermometer has been compared with the reversing thermometer, and this comparison has — within the range of the errors of observation — corroborated the correctness of the above table. As an instance may be noted St. Da. Atl. 4 ($^{22}/_{8}$ 1903), (See Bulletin des résultats ... 1903—1904 No. 1), where m indicates the depth in meters, d the difference between the indications of the reversing thermometer and the water-bottle thermometer and C the correction computed after the above mentioned table.

m	d	C
1700	+ 0·06	0·05
1400	0·05	0·04
1000	0·03	0·03
800	0·01	0·02
600	0·03	0·02
400	0·01	0·02

The reversing thermometer was divided in $^1/_5$°; uncertainty in the reading 0·01 − 0·02; consequently the conformity perfectly satisfactory.

To get an idea of the insulating powers of the water-bottle, the time, when the hauling up commenced, was noted in some cases, and the water-bottle having come up, the thermometer was read with short intervals. Ex. St. Da. Atl. 5 ($^{14}/_{8}$ 1903 l. c.).

[1]) W. THOMSON: „On the Dynamical Theory of Heat etc.". Transactions Royal Society of Edinburgh XX (1853) p. 283. Proceedings of the Royal Society 1857 VIII No. 27 p. 566.

[2]) J. P. JOULE: "On the Thermal Effects of Compressing Fluid". Philosophical Transactions, vol. 149 (1860) p. 133—136.

[3]) FRIDTJOF NANSEN: On Oceanography of the North Polar Basin. I. p. 5. Christiania 1901.

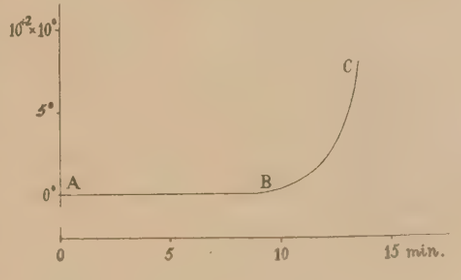
Hauling up commenced 4^h24 from a depth of 985 m.

Time	Reading
4^h30	−0·70
4^h32	−0·70
$4^h33{\cdot}5$	−0·70
4^h35	−0·69
4^h36	−0·68
4^h37	−0·62

From this example will be seen that though the water-bottle passed a warm water-layer which was more than 400 meters deep, the temperature kept constant for about 10 minutes, when it began to rise slowly, and after a short time quickly. The temperature of the air was about 10°, when the experiment took place. In such cases where it might be feared that a rise of temperature would take place during the hauling up, the thermometer was read twice with an interval of 1 or 2 minutes, but only in a very few cases a rise was observed. In the determination of temperature from 1500 m. at St. 26 the temperature began to rise after the first reading, but two comparisons with the reversing thermometer gave a correction on the water-bottle thermometer of + 0·07, so that (compare the table above) the supply of heat cannot have amounted to more than 0·01° C.

Nor does the friction, during the hauling up, seem to have had any considerable influence on the indications of the thermometer.

The experiments which were made in order to determine the rate of warming of the water-bottle under given outer circumstances did not prove any great conformity. The change of temperature proceeded in a curve of this appearance but the horizontal part *AB* could under perfectly equal outer circumstances be of different length. The longer the horizontal part *AB* was the greater the curvature of part *BC* seemed to be. So the result of the experiments seems to be negative, that is to say, that on several readings of the temperature, when it is rising, we cannot find the temperature *in situ* by extrapolation but must determine it by the reversing thermometer. The cause of the irregularities in the insulating powers of the water-bottle is not easy to tell. Professor FRIDTJOF NANSEN[1]) has studied the warming of a water-bottle under different circumstances without getting any positive result. It is possible that the irregularities arise from the fact that the india-rubber packings which close the ends of the insulating cylinder, sometimes, on closing take up a warped position, and thus leave open small spaces for the supply of heat between the edges of the packings and the cylinder, which fact the above mentioned appearance of the curves seems to intimate, as the slow rising originates in the transmission through the openings which are found at the india-rubber packings, and only when the supply of heat through the insulating walls can urge itself, a quicker rising of temperature will take place. The supply of heat through the insulating concentric cylinder must necessarily be supposed to be the same under the same outer circumstances.



[1]) FRIDTJOF NANSEN: On Oceanography of the North Polar Basin I. p. 11.

Discussion of the Sections Taken in May-July 1903.

Section I.

The section stretches from the northeastern part of the Faroe Islands in true north to 63°36′ n. lat., a length of about 75 miles. The soundings give a considerably larger inclination of the bottom of the sea north of the Faroe banks than formerly supposed; thus St. 3 lies south of the 500 fathom curve indicated on the chart, while the sounding in August gave a depth of 1740 m. (the sounding in May uncertain). The inclination from St. 2 to St. 3 thus amounts to 1740—130 = 1610 m. at a distance of 32 miles. If the earth quadrant is put to 10^7 m. the inclination will be 0·0272 or about 1 : 37 = 1°34′, that is 5 times as great as the average value for the inclination of the slopings towards the Norwegian Deep indicated by Mohn[1]). From St. 3 the depth then increases more slowly towards the deepest part of the Norwegian Sea (The Norwegian Deep).

St. 4 is situated on the border of the warm Atlantic water and the East-Icelandic polar current. Still the surface temperature is 3°5, and this as well as the comparatively great salinity in the upper layer (down to 50—75 m.) shows an evident influence of the Atlantic water. There is no doubt, however, that a few miles farther to the north prominent polar water will be found. This is suggested partly by the fast fall of the surface temperature (compare Sections III and IV), namely a few degrees at 3—4 miles, partly by the cold and very little saline water at the depth of 75 meters.

The three stations thus form a transverse section across the warm Atlantic water which after having passed the Faroe-Iceland-ridge moves northward of the Faroe islands into the Norwegian Sea. This warm surface current thus has a considerable breadth, about 75 miles, while the thickness of the water layer at most amounts to 250 m., that is to say the extent has been considerably diminished after the water having passed across the Faroe-Iceland-ridge, the thickness of the warm layer of water being 400—500 m. during the passage across the ridge. Provided that the greater part of the quantities of water, which have passed the ridge from the south, are moving in eastern direction to the north of the Faroe islands, we must at this place have a considerably greater speed of current than farther towards the west.

Remarkable is the course of the 35‰ isohaline. The tongue which at a depth of 200 m. stretches into St. 4 has evidently arisen in this way that the Atlantic water has stretched farther towards the north, but that the rather strong northern winds prevailing in the previous period have driven the polar water out over the Atlantic water. The named tongue has then been left behind, been cooled by the cold water, and is now sinking downwards. The density of the surface layer (down to about 350 m.) is considerably greater at St. 4 than at St. 3. So the pressure in a depth of 350 m. will be greater at St. 4 than at St. 3, and consequently effect a movement towards the place where the pressure is the weakest. As the masses of water which are moving towards the south have the greatest specific gravity, the movement will also be descending. This agrees with the tongue of less saline water which from the north stretches into St. 3 between 300 and 400 m.

We observe the great salinity to the very bottom at the northern slope of the ridge. It has probably arisen in the following way: the polar current has during the winter stretched farther towards the south across the slope between St. 2 and 3. So the salt Atlantic water has been much cooled (and mixed), and has sunk down the northern slope. As the specific gravity in the lower layer is greater at St. 3 than at St. 4, while the pressure at greater depths is about the same at the two stations, the heavier water in the lower layer at St. 3 will sink downward and extend northwards along the bottom. If the hypothesis

[1]) H. Mohn: Nordhavets Dybder, Temperatur og Strømninger. Den norske Nordhavsexpedition 1876—78 B. XVIII. p. 1 and 8. Christiania 1887.

mentioned above as to the origin of this bottom layer is correct, the great salinity must also by degrees disappear.

The temperature in the surface layer in the section in question is about 1° lower than that of those situated farther to the west. As the salinity is considerably higher than in the more western sections, and has the standard value for Atlantic water, a mixture with polar water is excluded as the cause of the low temperature. As mentioned above, however, northern winds were at a previous period prevailing at the Faroe islands with a temperature a little above the freezing point, and no doubt they effected a considerable cooling of the surface layer. At St. 2 and 3 the temperature is thus rising a little from the surface downwards, and the temperature is rather constant down to a depth of 100 m., which proves that convection currents have taken place in consequence of this cooling of the surface water.

Though the volumes of air cooled by the polar current have moved across a belt of warm water, 75 miles broad, they have still preserved their prominent cold character, and thus it will not be justified to draw any conclusion from the temperature of the air at the Faroe islands as to the distance of the polar water from the latter (Martin Knudsen: Iagttagelser over Overfladevandets Temperatur og Saltholdighed paa islandske og grønlandske Skibsrouter i 1899 p. 33, København 1900). Further the warming of the air by the motion across the warm water layer will be highly dependent on the speed with which the motion takes place.

The direction of the warm Atlantic current, which is in its main features north-eastern, has in the section in question been altered to an eastern one. The East-Icelandic polar current which moves through the Jan Mayen-channel in a southern or southeastern direction, and the warm Atlantic water flowing towards the northeast meet to the north of the Faroe-Iceland-ridge, and the resulting movement goes towards the east, till, on the western side of the current passing through the Faroe-Shetland-channel, it turns again and assumes its former direction towards the north-east and north, in order to join, later, the rotation movement in the Norwegian Sea[1]).

Section II.

This section goes approximately right-angled on the Faroe-Iceland ridge and forms an angle of about 45° with section I. This section, at any rate the southern part of it, goes nearly in the direction of the surface current which is seen as well from the course of the isohaline of 35·25 ‰ (see the surface-map) as from the course of the isotherms and isohalines, these showing a slight inclination towards the south. Near St. 5 the isotherms and isohalines approach to the surface. The movement here begins to be the above mentioned eastward movement, which is effected by the East-Icelandic polar current. The 35·00 ‰ isohaline has towards the north the same irregular course as mentioned under section I, St. 4 belonging to both sections.

If we consider the two extreme stations 4 and 7, we see that at the same depth there is a considerable difference between the specific gravities at the two stations. This difference in the specific gravity will cause a difference of pressure which is almost proportional to the depth, and which at a depth of 600 m. is found to be about 26800 cgs.[2]). If we imagine two horizontal tubes connecting the two stations, one at the surface, and one at the depth of 600 m., and two perpendicular ones at the two stations, we shall get a water movement from St. 7 to St. 4 in the upper tube and from 4 to 7 in the lower, together with an ascending movement in 7 and a descending movement in 4. — Similar conditious hold good for the interjacent stations 5 and 6, the pressure increasing uniformly from St. 7 to St. 4. — This movement in reality takes place. The surface current goes across the ridge in northeastern direction, and the thickness of the warm water layer decreases the farther it gets towards the north. The cold under-

[1]) Compare H. Mohn: Nordhavets Dybder, Temperatur og Strømninger.

[2]) Helland-Hansen & Sandström: Ueber die Berechnung von Meeresströmungen, Bergen 1903.

current — the reaction current — has no considerable development on account of the friction against the warm water which moves above in the opposite direction, but there is no doubt that such a current of cold bottom water takes place across the ridge. It is possible that this movement takes place by jerks (MARTIN KNUDSEN: Den danske Ingolfekspedition), but it is more probable that it takes place continuously, chiefly limited to the deeper parts. The existence of this current is proved by the fact that the temperature as well as the salinity at the bottom in St. 7 is considerably lower than the standard ones for this depth in the warm Atlantic water south of the ridge. Isotherms and isohalines go on the southern side of the Faroe-Iceland-ridge approximately parallel with the bottom[1]), and not, as might be excepted (without a reaction current) parallel with the surface. The reason is that cold water is continually streaming across the ridge. The colder water which is passing the ridge from the north has, namely, a greater specific gravity than the volumes of water which are in the same depth on the southern side of the ridge, and so it will move down the southern slope of the ridge, being by degrees warmed by and mixed with the warmer and more saline Atlantic water.

During the passage across the ridge a rather intensive mixture of the two water layers probably takes place, as the relative speed with which they pass each other is the greatest here. During the movement down the southern slope of the ridge the relative speed is gradually diminished, the speed of the current decreasing with the depth, and the greater the depth is, the slower the mixture of the bottom water takes place. This view agrees with the conditions which the Ingolf-Expedition found in the waters south of the Faroe-Iceland ridge.

Section III.

This section goes about in the direction south-north, parallel with Section I. — The 35·25 ‰ isohaline, which in Section I lay at a depth of about 200 meters, and in Section II at a depth of 400 meters, rises steeply towards the surface between St. 7 and 8. The salinity in the surface, however, only varies very little. The variations are of the same value as the errors of observation. The 35·00 ‰ isohaline goes, as in the two latter sections, down towards the northern slope of the plateau, so that the salinity at the bottom on the eastern part of the plateau is above 35 ‰. The temperature at the bottom in St. 8 is, however, about 1° lower than in St. 6, situated at the same depth to the east, and the salinity, too, is a little lower. This suggests that the cold reaction current along the bottom is more prevailing towards the west.

As mentioned under Section I the mixture area between cold and warm water is also very narrow here. In St. 10 the influence of the warm water is rather insignificant, while two surface samples respectively 5 and 15 miles from there gave temperature and salinity respectively 3°3, 34·88 ‰ and 6°6, 35·23 ‰, the latter consequently strongly marked Atlantic water.

The differences in the specific gravity between St. 7 and St. 10 are a little slighter than for the extreme stations in the last section, of which follows a little less difference of pressure per unit of length. The powers which effect the interchange of the water volumes on both sides of the ridge are consequently a little weaker in this section than in the former. When the movement along the bottom seems to be more marked here than in Section II, it is possibly owing to a less speed of the surface current, and consequently a feebler resistance against the movement along the bottom.

Section IV.

The section stretches from the south-west to the north-east, parallel with Section II, its length is about 110 miles. As the most northern station (10) is lying within the boundaries of the East-Icelandic polar current, and the section is going in the same direction as Section II, rather analogous conditions

[1]) MARTIN KNUDSEN: Den danske Ingolf-Expedition. København 1898.

must be expected. And so it is in the main. The isotherms and isohalines have nearly the same course as in Section II, rising to the surface towards the northern part of the section. There are, however, a good deal of essential differences. The 7° isotherm which in the southern part of Section II was lying at a depth of above 400 meters, and only reached the surface near St. 5, is in Section IV lying quite near the surface, and has in this section almost the appearance of having arisen from a warming up from the atmosphere at the commencing heat of summer. There was also found in Section II a water layer of a thickness of about 400 meters with a salinity of more than 35·25 ‰, while water of a salinity of more than 35·25 ‰ does not at all appear in Section IV except at a very small territory round St. 11. On the whole the salinity is considerably smaller than in Section II, and the 35·00 ‰ isohaline which in the preceding sections has gone down towards the northern slope of the Faroe-Iceland-ridge is at a distance of about 100 meters from the bottom here.

The temperatures in Section IV are uniformly a little lower than in the preceding sections, especially the temperature at the bottom in St. 12 is 0°2. This low bottom temperature in connection with the low salinity of the bottom water shows, as already in the preceding section, that the interchange between the water volumes in the two basins divided by the Faroe-Iceland-ridge is chiefly going on in this way that the warm surface current passes across the eastern part of the ridge while the cold under current is essentially limited to the western part of the ridge. This is possibly a consequence of the influence of the rotation of the earth which will certainly turn the warm current coming from the south towards the east and the south going one towards the west.

The difference of the specific gravity is considerably smaller here than farther towards the east. The increase of pressure per unit of length thus is decreasing towards the west though the bottom current called forth by the distribution of pressure reaches its greatest development just here. So there must be other causes, as for instance a higher level of the polar current in proportion to the Atlantic water, a higher atmospherical pressure, and, as above supposed, a lesser speed of current of the warm surface layer; the deflecting effect of the rotation of the earth will also contribute to the shifting towards the west. — The most probable reason, however, is certainly to be found in the East-Icelandic polar current itself. The motion in it is a cyclonic rotation [1]), so that we get a movement towards the south along the eastern coast of Iceland, and part of the volumes of water partaking in this movement then make their way across the western part of the ridge while the other part is deflected parallel with the ridge and continues its rotating motion in the Norwegian Sea.

Section V.

This section stretches from St. 13 in true north to St. 17 which is situated east of the Reydarfjord. The extension of the section is 106 miles. While the former sections were stretching across the Faroe-Iceland-ridge and especially on its northern side were reaching greater depths, this is not the case with Section V, the rising of the bottom of the sea towards the coasts of Iceland here commencing to appear at St. 15 and especially at St. 17, where the depth is only 207 meters. Characteristic of the above mentioned sections was a nicely continuous course of isotherms and isohalines and a smooth rising of them towards the north. In Section V, however, more complicated conditions seem to be prominent. In the southern part of it we find a bottom layer of the thickness of about 200 meters with low temperature and a salinity of less than 35·00 ‰. The surface layer above shows at the same time a strikingly low temperature and salinity (St. 14). At St. 15, situated northlier, the cold bottom layer with low salinity has disappeared, and the whole station shows a high temperature from the surface to the bottom. At St. 16 the temperature is again decreasing and approaches to 0° towards the bottom, the salinity, however, con-

[1]) H Mohn: Nordhavets Dybder, Temperatur og Strømninger.

tinuing to be more than 35 ‰. St. 17, however, clearly exhibits polar water with low temperature and salinity. We have no dates for the determination of the course of the 35 ‰ isohaline, as we only know that it goes from the surface to the bottom between the two stations 16 and 17. A surface sample between the two stations with temperature 1°2, salinity 34·85 ‰ evinces that it must be nearest to St. 16.

The most diversified, sharply bounded volumes of water which appear in this section prove, that it does not go in the direction of the movement of the water, consequently as little in the direction of the surface current as in that of the under current. It has however plainly the character of a section perpendicular to the direction of the current. The low temperature and salinity at St. 14 must be supposed to have arisen from the fact that the polar current, before the state mentioned here occurred, sent a tongue towards the south through this section, or probably farther towards the west along Iceland. An intense current of warm water has then moved along the south eastern coast of Iceland, and has made its way through the polar water, which gradually partly loses its character by warming up and mixture, partly sinks down to the bottom, and moves towards the south or southwest. The warm surface current will quickly alter its moving direction, and then will go approximately towards the east or east-south-east, which appears in Section IV by a lowering of the 35 ‰ curve as well as of the specific gravity curves.

A consideration of the sections V, IV, and III proves by the bottom conditions found in them that the polar water exercises a considerable influence on the bottom water in these sections, especially in the two first named. Here we have a cold under current which makes its way across the western part of the ridge and goes farther down into the basin of the Atlantic ocean. To judge from the distribution of temperature and salinity this current seems to go from the north-east to the south-west, parallel with the south-eastern coast of Iceland, and to be directed towards the deepening in the bottom of the sea, which is found south-east of Iceland.

If we compare the above mentioned sections with the sections XXII, XXIV, and XXIII of the Ingolf-Expedition, we find rather analogous conditions, though each of the stations of these latter ones have been taken at very different times (May and August). Essentially we find the same low temperatures at the bottom, St. 52 of the Ingolf-Expedition excepted, but the low salinity at the bottom makes the determination of temperature 7°9 very much improbable. A consideration of the Ingolf-Expedition chart of the distribution of the temperature and salinity at the bottom shows as well low temperature as low salinity on the territory mentioned here.

The cold bottom current mentioned here thus seems to exist as well in different seasons as in different years, and must, probably, be a constant phenomenon, which plays a considerable part for the bottom layers in the northern part of the Atlantic Ocean.

Section VI.

Besides the sections I—V, which are chiefly going across the Faroe-Iceland-ridge, hydrographic researches were made in a section in east-western direction from St. 17 to Seley, situated outside the mouth of the Reydarfjord. So the section stretches across the coast flat; the greatest depth is 207 meters (St. 17). The three stations in this section offer rather uniform conditions. The temperature is about 1°, only at the deepest station (17) it sinks to 0° in the lowest layers. The salinity decreases very little towards the coast, and is quite constant from the surface to the bottom at the two stations situated nearest to the coast, while the salinity at the bottom at St. 17 seems to grow a little towards the bottom. The same is the case with the specific gravity. Though the difference in the specific gravity is only slight, there is a tendency to a surface current from shore and an under current towards shore. We have possibly a suggestion of this at the bottom at St. 17. Possibly we have also a higher level on the coast of Iceland on account of the deflecting effect of the rotation of the earth which will counteract the

bottom current provided that the speed of current is decreasing from the surface downwards. We might expect a rather strong surface current from shore at this season, but on account of the cold spring in Iceland the supply of river water has only been scarce during the preceding time.

Besides these sections which include all the stations at which the quarterly researches have been made, we shall mention a few longitudinal sections through the stations on the Faroe-Iceland-ridge, as these sections are approximately going on the square with the above mentioned ones, and might thus give such informations as to the motional conditions of the water as do not appear from the above mentioned sections.

Section VII.

The section stretches from Iceland in southeastern direction towards the Faroe islands. In the southeastern part of the section is found water of a salinity of upwards of 35·25‰, but only at St. 6, not at St. 8. Farther towards the northwest is found bottom water with a salinity under 35‰, and we also see that the bottom temperature is decreasing towards the northwest though the section is going in the longitudinal direction of the ridge. So we have an evidence of the greater development of the above-mentioned bottom current across the western part of the ridge. The surface temperature being so near 7° it is no wonder that the 7° isotherm has a rather irregular course. The differences of the specific gravity are very slight and of no real importance. We may observe the curves for temperature 5° and specific gravity 27·75; their course is practically speaking horizontal and thus shows that the high bottom temperature at St. 15 as mentioned above arises from the situation of the station on the coast flat where the depth is too small for the cold bottom water to make good its influence. When the little disparities in the surface layer are excepted we see that the specific gravity curves are going almost horizontally, so that the gravity will not in any considerable degree contribute to any motion of the water parts in the longitudinal direction of the section in question. The conclusion that such a motion will not take place would, however, be most illegitimate, as there may be many other causes for such a one, as for instance different atmospherical pressure, differences of level, the wind, and finally the water parts may be in possession of kinetic energy which will keep up the motion.

Section VIII.

This section goes from Iceland to the Faroe islands parallel with the former, and is situated at a distance of about 40 miles from it. Still it differs very much from it because we are now approaching to the borders of the Atlantic current. In Section VII water of a salinity of above 35‰ was stretching to the very bottom in the greater part of it. In Section VIII the salinity at the bottom is not so great except on the Faroe banks in the eastern part (St. 2). We have, however, uniformly considerably greater depths in VIII than in VII, but the fact that this section is situated on the northern decline of the ridge is not the single reason of the lower salinity at the bottom, for we see that the Atlantic water has a considerably slighter thickness than in Section VII; the greatest depth of the 35‰ isohaline is about 300 meters (St. 9) from whence it rises much on both sides; the temperature too has an evident maximum at St. 9, and even decreases more than 1° to the east to St. 5, where the salinity is also lower.

This state of the surface layer must necessarily be supposed to arise from sheer local conditions of wind which at the stations 9 and 11 have shifted the border-line between the warm and the cold water towards the north, while this border-line round St. 5 has removed towards the south.

It is a wellknown fact that this border is subject to rather quick shifts on account of the existing conditions of wind, and thus we had northern winds at the stations 2, 3 and 4, while the wind at St. 5 changed to the east and then to the south, from whence rather powerful winds were blowing for a few days (until 13·2 $^{m}/_{sec}$) till station 9 was taken. We have thus a good connection between the direction of the wind and the appearance of the border-line.

Section IX.

The section includes the stations 20—23, which were taken towards the close of May in north-eastern direction from the Seydisfjord, and thus are all situated in the East-Icelandic polar current.

The surface temperature is low everywhere from 0°6 to 1°4, but varies without regularity, a circumstance which is refound in the surface salinity. In the extremest part of the section we have the minimum of temperature characteristic of the East-Icelandic polar current with a temperature below 0°. Here it seems to lie a little deeper than generally, which is probably arising from a greater supply of the surface layer, the temperature of which is upwards of 0°. The upper 0° isotherm seems to rise nearer to the surface towards the east.

At the two stations 20 and 21, situated at a depth of 200 or 300 meters we have a higher bottom temperature than farther to the east at the same depth; at St. 21 we have even a temperature minimum of about 0°2 at a depth of 100 meters from whence the temperature again increases a little downwards, but this minimum in temperature has evidently no communication with the minimum that is found farther to the east with a temperature below 0°, for we see that the 0° isotherm from the east is stretching towards the bottom at St. 21. Such an increase in temperature is found near the north of Iceland (see Section XIV) where it arises in consequence of the east going under-current of warmer water (the eastern branch of the Irminger current), and it is possible that we have here a continuation of this under-current, but we see that its influence is very insignificant, and that its existence can only be proved by very exact measurings of temperature.

Section X.

Section X includes the stations 26, 27 and 28, which were taken towards the close of May from Vestre Horn in southern direction till a distance of about 60 miles from shore. The section also includes the stations 25 and 24 of which the latter is situated off the Reydarfjord, about 2 miles from station 19, which was taken on the 16th of May. During the preceding 13 days a rather considerable change has taken place; the temperature, as well as the salinity is now decreasing downwards to the depth of about 20 meters, from whence, as before, it keeps constant to the very bottom; but while the salinity, practically speaking, has the same value as on the 16th of May, the temperature now is about 0°6 higher; a circumstance which indicates that this whole water layer has in the mean time been renewed, and the rise of temperature makes it probable that this renewal has taken place from the south.

On the 26th of May a current bottle stranded at Vadlavik near the Reydarfjord; it had been thrown out at 45° north latitude, 35° west longitude, and it is probable that it has come along the coast from the south, as, if it had passed round Iceland, it must have moved in a somewhat northern direction through the Atlantic ocean. Its mean speed, 3·8 miles in twenty-four hours, at the same time agrees so well with earlier current observations in these waters that there is no reason to suppose that it has gone west and north round Iceland. Thus both these circumstances indicate, that a northgoing motion has taken place towards the close of May and made itself urgent along the coast till 65° north latitude.

St. 25, situated a little south of Berufjord, shows proportionally high temperature and salinity, which characterises these waters as mixture water of prevalent Atlantic origin; a little under the surface is found a minimum of temperature, evidently arising from the coast water.

The three stations south of Vestre Horn are situated in strongly marked Atlantic water, and show rather uniform conditions. The surface temperature as well as the salinity decreases a little towards the shore; the variation in temperature is only 0°5, in salinity 0·08‰, which proves that the influence of the coast water is about the same, and to judge from the salinity very insignificant; even at a distance of 4 miles from Vestre Horn the temperature in the surface was 7°70 and the salinity 35·16‰, from which also appears that the polar water at this time was not at all perceptible off Vestre Horn.

The temperature and the salinity only vary a little and rather smoothly with the depth; at St. 26 — from whence the bottom of the sea ascends very much towards St. 27 — the temperature as well as the salinity decreases faster beneath 1000 meters, and at the depth of 1500 meters they are respectively 3°10 and 35·03‰, that is to say: we have here the bottom layer influenced by Arctic water.

Section XI.

In connection with the last mentioned section we shall here discuss a series of stations which were taken from the Westman islands in southern direction during the first half of July. Here we have, on account of the advanced time of the summer a considerably (more than 2°) higher temperature in the surface, but the surface temperature shows considerable and very irregular swingings which evidently arise from a warming of the atmosphere. In those days we had a clear sunshine with calm or very gentle winds, and at about the same place was observed a variation of temperature in the surface of about 1° in twenty four hours.

When we except the higher temperature in the surface layer, the conditions are quite the same as in Section X as to the variation of the temperature and the salinity with the depth so that, on the whole we refind the picture of the conditions in the waters south of Iceland given by the hydrographer of the Ingolf-Expedition. Nearest Iceland water is found with a salinity below 35‰ (St. 50 and 54) as consequence of the supply of fresh water from the rivers. The lowest value observed is 34·87‰ (about 5 miles from shore) and from there it grows rather regularly from the coast and gets rather constant towards the extreme part of the section. Such a distribution of the salinity suggests that the cause of this spreading of the fresh water is that it on account of its lower specific gravity flows out over the heavier salt water and is gradually mixed with it.

Much more complicated conditions may, however, occur on account of local conditions of wind. Thus a series of surface samples south of Portland show a salinity of 34·32‰ at a distance of 35 miles from the coast, and a minimum of salinity (33·15‰) at a distance of about 12 miles from it, whereafter the salinity grows towards the shore, and even reaches the value of 34·97‰ a few miles from the shore. On the two preceding days rather powerful northern and northwestern winds were prevailing (strength 6—8 Beaufort) and thus they have torn the surface water away from the coast, so that the more saliferous underlayer reaches up to the surface near the shore. We have also an indication of a minimum of temperature nearest the shore in connection with the highest salinity, which also indicates that this has been an under-layer. That the under-layer is thus laid bare under a coast, because a land-breeze carries the surface layer into the sea, is a wellknown phenomenon which often reaches a great extension, thus for instance the colder water which is found under the coast of Guinea according to Puff[1]) arises in this way.

[1]) Puff: Das kalte Auftriebwasser, Marburg 1890. Further: John Murray: Scotch Geographical Magazine 1888. p. 345.

Sections XII and XIII.

From the 10th to the 14th of June some researches were made in the Denmark Strait of which the results are given in Sections XII and XIII, Section XII stretching from the mouth of the Faxe Bay about 135 miles to the west, while Section XIII is situated at about 65° north latitude, the direction of it conforming to the form of the ice edge but in the main going from west to east.

Section XII shows only very little variation as well in the temperature as in the salinity. Nearest Iceland the salinity is diminished a little on account of the supply of river water, and the specific gravity is a little lower than farther to the west, but the difference is so slight that it is scarcely of any importance.

The surface salinity is constant in the western part of the section; at larger depths the temperature, as well as the salinity, seems to decrease faster with the depth, which appears by a rising of the 35·10 ‰ isohaline and the 6° and 5° isotherms. This seems to indicate that we are here approaching to the western border of the northgoing motion in the Denmark Strait. But, as mentioned above, the variation in the temperature as well as in the salinity is only slight.

In Section XIII which is situated farther to the north such a bent of the 6° isotherm is not found, and in this section it appears as a closed curve which is lying at a considerable distance from Iceland. The westgoing movement of the warm water in the northern part of the Denmark Strait (M. Knudsen: Den danske Ingolf-Expedition) has thus asserted itself here. Both the temperature and the salinity are uniformly a little lower in this section than in the more southern, which is natural, as these volumes of water during their motion towards the north yield heat as well to the atmosphere as to the colder bottom layer, and get their salinity diminished by mixture with coast water, and influences from the East-Greenlandic polar current may possibly assert themselves at a greater distance from it.

That the 6° isotherm appears as an almost closed curve arises from the nearness of the Greenland ice, as the ice-water from the ice edge is spreading over the surrounding waters; this layer of ice-water is generally very thin (its thickness, of course, is dependent on the distance from the ice edge), and it does not stretch many miles from it. At Station 34, which was situated at a distance of about 6 miles from the ice edge, the influence of the ice-water is very insignificant (temperature 7°11, salinity 34·97 ‰) which suggests that the ice itself is moving towards the south with a rather considerable speed, a supposition which was confirmed at St. 38, for here was observed a deflection of the ice border of about 1 mile an hour.

As mentioned above the thickness of the ice-water in the surface is only slight. As to St. 35, which was situated about a mile from the edge of pack-ice, and at which was found a deal of spread drift-ice, the ice-water can only be traced at a depth of a little more than 30 meters, and at a depth of 10 meters its influence is already comparatively slight. At St. 36, the distance of which from the ice edge was 4—5 miles, the influence of the ice-water is not to be traced at the depth of 10 meters, though from 0 to 10 meters we have a rise in the temperature of 4°4 and 2·0 ‰ in the salinity. At St. 37, the distance of which from the pack-ice is 1·5 miles, the ice-water seems to have asserted its influence till upwards of 50 meters, but here we must remember that we are approaching to the coast of Iceland, where we find particular conditions, as the salinity of the surface layer will be reduced beforehand on account of the influence of the coast water.

As mentioned before we see from the eastern part of the section that the Irminger-current off the northwestern land begins to lose the character of an Atlantic current partly in consequence of the mixture with the cold and fresh water from Iceland, partly — which in this case must be supposed to be the most important cause — because the East-Greenlandic polar current sends its ice volumes towards Cape Nord and farther towards the south-west near the northwestern land by which it forces the greater part of the waters of the Irminger-current towards the west, while only a small part in a cooled and much mixed condition reaches past the northwest point of Iceland.

Section XIV.

In continuation of the last section we shall mention a section through four stations north of Iceland from Cape Nord to Grimsey. They are all rather near the coast and on shallow water, so we have a very low salinity in the surface.

The temperature decreases a little from the west to the east through the whole section (a little more than 1° for the surface, at the bottom 2°) and its variation with the depth is only slight; at the most western Station 40 (Cape Nord) the temperature thus decreases from 5°30 in the surface to 4°82 at the bottom. In connection with this proportionally high temperature is found a very low salinity (34·18‰ in the surface, 34·56‰ at the bottom) from which we conclude that this water layer which from its high temperature appears to be a continuation of the Irminger-current, has been subject to a mixture with water of a very low salinity, f. inst. river water, or the ice-water from the ice edge which is very much deficient in salt, as a mixture with Arctic water of a salinity of 34‰ or more would reduce the temperature of the mixture in a much greater degree than has been the case.

Farther to the east the temperature, as already mentioned, gets a little lower, and decreases faster with the depth, reaches a minimum, and grows to a maximum to decrease again towards the bottom. The difference between this maximum and minimum temperature is, however, only slight; at Grimsey, for instance, where it was greatest, it was only 0°6—0°7.

This apportionment of temperature is analogous with the state in the East-Icelandic polar current, but that we have not to do here with the waters of the latter is seen from the high temperature which might perhaps have arisen from a mixture with warm surface water from the coast, but when, for instance, at Station 41, at a depth of 60 meters, we have a temperature of 4°0 in connection with the salinity 34·83‰, such a warming up is excluded on account of the high salinity.

The cause of the conditions mentioned here must, however, be sought in the eastern branch of the Irminger-current.

The waters in the Irminger-current which from southern regions are carried northward along the western coast of Iceland meet the East-Greenlandic polar current off the northwest land, and together with it they are led back through the Denmark Strait, while a larger or smaller portion — according to the greater or lesser distance of the East-Greenlandic polar current from Iceland — passes the northwest land and is deflected towards the east partly by the polar current and partly on account of the rotation of the earth. As the ice is generally not to be found very far away from the northwestern land, there will, from the ice edge be an ample supply of cold and very slightly saliferous ice-water (32—34‰), which as it is generally lighter than the warm, but salter water, will flow out over it which is thus cooled and will sink farther downward; by this process the salinity will also be decreased, partly by diffusion of salt, partly by mixture.

In the bottom layer with its maximum of temperature we have thus chiefly water of Atlantic origin (certainly in a very considerably mixed form), while the surface layer has the character of polar water by its low salinity and quick decrease in temperature with the depth, even if this decrease is not so typical as in the very polar current, because the surface layer is here resting on warmer water and is thus warmed up from beneath.

In the minimum of temperature we have here the border between the two layers of different origin; thus we see that in the minimum of temperature we have the greatest variation in the salinity.

Unfortunately we have no observations informing us of the extent towards the north of this current which is sure to play a considerable part for the fauna of the sea north of Iceland.

Discussion of the Sections Taken in August 1903.

Section I.

This section was in August, when the regular Stations 2, 3 and 4 did not give a more northern border for the warm Atlantic water, continued towards the north by the Stations 4 A, 4 B and 4 C. Station 4 B was taken August 15th but still gives a good connection with 4 A and 4 C, which were taken on the 23th of August.

The surface temperature is about 3° higher than in May, and is almost constant in the whole section in spite of the considerable variation of the surface salinity. As to the northern part of the section this is essentially a consequence of a warming up from the sun and the atmosphere, still a mixture with Atlantic water is not excluded, but the quick decrease of temperature with the depth shows that this mixture has only been of lesser importance. The warm Atlantic water, which in May reached down to 200—250 meters at Station 3, in August at the same station reaches 350—400 meters, from whence the thickness diminishes towards the north, and at Station 4, where it was not found in May, it has still a thickness of about 300 meters and stretches from thence at least 40 miles farther towards the north, beyond Station 4 A. Thus it stretches 40—50 miles farther to the north than in May and its transverse section is 3 times as great as in May. The surface layer with a salinity of under 35·00 ‰ on the border district had in May a greater specific gravity than the warm water, which is probably standard for the winter state, while in August it is lighter in consequence of the comparatively high temperature in the surface, which in this section causes that in St. 4 A it flows out over the Atlantic water and stretches at least 30 miles down over it. This layer, however, is very thin — to judge from the salinity at St. 4 A it cannot be traced to more than 50 m. depth.

The greater extension of the Atlantic water in summer than in spring probably arises from a periodicity in the Atlantic current. Thus O. Pettersson[1]) states that the latter has in winter its annual ebb-period. When the same author states (p. 160) that the branch of the East-Icelandic polar current which goes along the Faroe-Iceland-ridge, in summer as an under-current, in winter even as a surface current, enters the Northsea plateau, this seems not to agree with the hydrographic conditions found by us, as the specific gravity of the surface water in the polar current, on the border of it as well as farther to the northwest (St. 22 and 23), as above mentioned, is greater than the specific gravity of the Atlantic water and cannot consequently be surface current over the latter. This must at any rate be said as to May and probably also as to the winter, as in winter the polar current has a considerably higher salinity than in summer, the supply of ice-water being least in winter. In summer when the supply of the ice-water, which is deficient of salt, gets ampler and the upper layer of it is warmed up by the sun and the atmosphere, this surface layer will be able to adopt a smaller specific gravity than the Atlantic water, and it will then be able to act as a surface current which, however, does not reach any large thickness (the maximum may safely be put to 30 meters). So we see that in August it flows down over the Atlantic water on the Faroe-Iceland-ridge, stretching a tongue to the north of the Faroe Islands and Shetland towards the coast of Norway[2]) to about 2° east longitude. The same state is seen also to have taken place in August 1902[3]). Thus in summer water of Arctic origin may appear in the Northsea as an surface current, but generally not in winter.

The high salinity which was found in the bottom layer at Station 3 in May has disappeared, as might be expected, but the change is so slight that the correctness of such a conclusion might be doubted

[1]) O. Pettersson: Ueber den Einfluss der Eisschmelzung auf die oceanische Cirkulation. Öfvers. Kgl. Vetsk. Ak. Förhdl 1899 No. 3, pag. 158.

[2]) See the surface map in Bulletin des résultats acquis pendant les courses périodiques, Août 1903.

[3]) Bulletin des résultats etc. Août 1902.

if it was based on the change of salinity alone. If, however, we compare the determinations of temperature from May and August at Station 3, we get the following values for the rising of temperature from May to August:

Depth	Rising of temperature
0 m.	3·47
100	1·67
200	2·54
300	5·76
400	3·79
500	2·20
700	about 0·7 (interpol.)
1000	0·34
1400	0·20

At a depth of 1000 meters the rising is 0°34, a change of temperature which, when we consider the depth, is rather considerable. As the change has been a warming up in connection with a decrease of salinity it cannot arise from convection currents as these always supply the under layer with heavier water; the transmission of heat is also excluded on account of the great depth (compare Section II). So the only possible explanation of this rising of temperature is that a supply of warm water has taken place, a supply which has asserted itself down to a depth of more than 1400 meters, and thus shows that the opinion sometimes stated, that the ocean water at larger depths is only very seldom renewed, does not hold good.

Whether the reason of this change is to be sought in a supply of more saliferous and heavier water to the bottom layer in winter which then moves farther down the decline towards the Norwegian Deep (as suggested at the discussion of the May observations, Section I) and is compensated for by other volumes of water, or it must be sought in currents nearer the surface, cannot, however, be decided here.

Section II.

In this section Station 4, which in May was entered into the section as the extremest northern station, is supplied with 4 F and 4 E. The state at these two stations is quite analogous with the stations 4 C and 4 B (the northmost part of Section I).

While water of a salinity of upwards of 35 ‰ was stretching wedge-like through St. 4 A (Section I), we have not, on the whole, at St. 4 F so high a salinity, though this station is situated a little more to the south than St. 4 A, and so the 35 ‰ isohaline ascends rather steeply to the surface south of this station. Water with a salinity of upwards of 35·25 ‰ is found in the southern part of the section (St. 7 and 6) and also at St. 4, but at St. 5 there is on the whole not found so high a salinity. This state is evidently due to the tongue of polar water which at 8°—9° longitude passes down into the Atlantic water (see St. 5 A and the surface map).

At the surface the temperature curves are almost parallel with it, still with a slight decline towards the south which becomes considerable in the southern part of the section, thus at St. 7 the 5° isotherm almost reaches the bottom (about 700 meters), while at St. 4 E it is found about 60 meters under the surface. The state at St. 7 is, excepting the higher temperature in the upper layer with a thickness of 300—400 meters, quite the same as in May. Station 6, however, proves a lower temperature as well as salinity at the bottom; thus the 35·00 ‰ isohaline is going down towards the bottom on the southern slope of the ridge. The northern part of the section from the surface to a depth of 600 meters shows a considerably higher temperature than in May. When the warm surface layer is excepted, the temperature is on an average 1° higher, and the 0° isotherm is lying about 150 meters deeper (at St. 4 at a depth of about 600 meters, while in May it was found at a depth of about 450 meters).

At the Norwegian stations 47 and 18, which are situated about $2^1/_2°$ farther to the north on about the same longitude we find the same conditions (in the earlier part of September). — So a rather considerable supply of heat must have taken place during the previous 3 months, and as the effect reaches so deep down it cannot arise only from transmission from the surface. We have namely a good deal of determinations of the speed with which the heat is transmitted downwards in comparatively quiet water (a closed fjord for instance), and the maximum of it is about 100 fathoms in one year[1]). The rise of temperature must, consequently, arise mostly from a supply of warmer water. This rather powerful water layer must be considered as a transition layer between the polar water and the Atlantic water, and must have arisen by the interaction between these waters, the border between the two waters having probably been subject to rather considerable deflections. From the Norwegian station 18, where the salinity is upwards of 35 ‰, we see that this water layer, of which the greater part has probably moved in eastern direction north of the Faroe-Iceland-ridge, when it meets the Atlantic current between the Faroe Islands and Shetland, is by the latter deflected in northern direction and on higher shores is deflected farther in western direction, forming the often mentioned cyclonic rotation in the Norwegian Sea. When this comparatively warm water which is found on the outer border of the rotating waters is moving towards the west it meets the polar ice and probably is the most important cause of the melting of the ice[2]). By this it is cooled almost to the freezing point — at all events under $\div 1°$ — and mixed with the ice-water. This effect is especially powerful for the upper layer (down to 100—150 meters), while below this we find a maximum of temperature at a depth of 200—300 meters of from 0° to 1° and a proportionally high salinity which indicates that the mixture does not reach this depth, but that the fall of temperature is owing to loss of heat by transmission to the cold water above and below. This surface layer with a minimum of temperature and under it a maximum then moves farther towards the south and the east and is characteristic of the proper East-Icelandic polar current.

If we compare the measurings undertaken by the Ingolf-Expedition in the East-Icelandic polar current, we see that the lower 0° isotherm which may be considered as the border between the proper bottom layer and the above mentioned mixture layer — or about parallel with it — is situated considerably lower to the north and the east than in the middle, from whence again it sinks a little to the west and to the south. It is nearest the surface on 66°—67° north latitude and 8°—10° west longitude, and at the same place we have the greatest thickness of the salt wanting and cold surface layer (the ice-water), while its temperature is also the lowest here. At this place we evidently have the axis of this rotation. For near the rotation axis the extension of the warm mixture layer, the intervening layer, will be the least, as the supply of it takes place from the edge of the rotating waters, just as the greater thickness of the ice-water at the surface is a direct consequence of such a rotation.

This rotation of comparatively warm mixture water must evidently be the cause why ice is comparatively rarely found for a longer time on the range Jan-Mayen—Langanes, nor is the ice-limit on this range subject to as great variations as for instance near Spitzbergen.

Section III.

For all the stations in this section the local designations are only approximative, as no determinations of position could be undertaken (haze and rain), and the wind was now and then blowing hard with a high sea which made the course unsafe. They are, however, all, especially the southmost ones situated farther to the west than the corresponding stations in May.

[1]) H. Mohn: Nordhavets Dybder, Temperatur og Strømninger p. 97. Further: O. Nordgaard: Studier over Naturforholdene i vestlandske Fjorde. I Hydrografi. Berg. Mus. Aarb. 1903 No. 8 pag. 28.

[2]) Otto Pettersson: Ueber den Einfluss der Eisschmelzung auf die oceanische Circulation.

Characteristic of the whole section, when the southmost station is excepted, is the low salinity of the Atlantic water. At the surface it is in St. 8 and 9 even below 35·00 ‰; in St. 8, however, this seems mostly to be owing to a supply of fresh water from Iceland, as the salinity is increasing very uniformly downwards, and the temperature is falling downwards, but in St. 9 the low temperature 6°—7° and the uncommonly low salinity (34·65 ‰) gives a secure indication of water of Arctic origin. The border between the two water layers lies between 45 and 50 meters, the temperature there springing from 6°24 to 7°50, on repetition giving 7°42. About one hour later when the work at the station had been finished a determination of temperature from 50 meters was again taken, but now it gave 4°58, and a sample from 60 meters gave 5°81 with a salinity of 34·85 ‰, from which we see that this tongue has a strongly marked wedge-like form. It arises (see the surface map) from the rather powerful point which the polar current, as formerly mentioned, sends down towards the south on 7°—8° west longitude. The latter is probably connected with the prevailing northern winds which sometimes reached a rather considerable power[1]).

The warm Atlantic water has a strikingly slight thickness; the 35 ‰ isohaline lies in a depth of only 150 meters and descends steeply towards the south side of the ridge. Above the ridge is found a rather powerful bottom layer in which is traced a great influence of polar water which, however, has not contrived to assert itself at the southmost station, 7 A, which shows predominant Atlantic qualities.

In the northern part of the section we have in Station 10 A a suggestion of the maximum of temperature characteristic of the polar current at about 200 meters, and the Atlantic influence is far less than at the same latitude in the former section. The 0° isotherm also lies considerably higher than in this one.

Section IV.

As in Section III the salinity of the Atlantic water is everywhere very low, and the 35 ‰ isohaline lies only a little deeper than in that one (175—200 meters); it sinks down till below 300 meters in the southern part of the section, but still it lies at least about 100 meters from the bottom. The bottom water has about the same salinity, it increases — as the temperature — a little from the north to the south. The comparatively cold and rather fresh water which was found at the bottom in Section III but did not reach the southern part of it stretches in beneath this whole section (IV) and as in May makes its way to the southwest across the Faroe-Iceland-ridge and into the basin of the Atlantic ocean, and this bottom current probably forms an important outlet for the waters of the East-Icelandic polar current, while another part is carried northwards through the Norwegian Sea on the western side of the Atlantic current.

In the section there is at Station 11 an area with a minimum of temperature and salinity at 50 meters; whether it is perfectly isolated from the polar water or whether it is in communication with it to the west or to the east (St. 9) cannot easily be decided. However it seems probable that it is in communication with the polar water in St. 9. As the two northmost stations of this section were also included in Section III we shall not mention the northern part here.

Section V.

In this section we have a considerably thicker layer of Atlantic water than in the two preceding ones; thus in the middle of the section it reaches quite down to the bottom (fully 300 meters), while towards the southern part we find the cold and little saliferous bottom layer which from the northeast juts itself down across the ridge.

The salinity at the southmost station is comparatively low, while at the stations 14 and 15 it is considerably higher and even reaches the value of 35·25 ‰. This supply of more saliferous water must

[1]) Bulletin des résultats acquis pendant le courses périodiques, Août 1903.

have come from the west, for towards the east as well as towards the south we have a lower salinity. The low salinity at Station 13 must be supposed to arise in this way that these waters under the coast of Iceland have been mixed with fresh water and then displaced by a current along the coast consisting of more saliferous water which has followed the coast till near Østre Horn (where the border of the Atlantic water was found in the midst of July) and then moved towards the east. In the surface of it we also find clear traces of the coast water from Iceland.

From the current bottles landed on the south coast of Iceland Captain C. Ryder[1]) concludes that the Atlantic current on about 12° west longitude is dividing fan-shaped, so that a branch is moving from the southeast to the coast of Iceland, while a greater part is entering the Norwegian Sea. The above mentioned distribution of the salinity cannot agree with this view and shows that this dividing cannot be any constant phenomenon, though it may possibly sometimes take place, as we have unmistakable criterions of an eastgoing movement here.

In the northern part of the section we have rather unmixed Arctic water; at Station 16 we still meet a wedge of warm water at a depth of 100 meters, while the salinity above as well as below does not seem to be influenced by the Atlantic water, it is, indeed, a little lower than at St. 17 which is situated more northward. This, however, may easily be explained by the fact that this little saliferous water has been carried along on the outer side of the warm current from the coast of Iceland, where the salinity on account of the great supply of fresh water from the rivers in summer is considerably lower than farther out to sea (see Section VI).

Section VI.

This section, which in May showed quite uniform conditions, has during the summer changed its character perfectly. That this change is owing to a great supply of fresh water from the rivers of Iceland is directly obvious when we consider the section. Thus Station 19, which is nearest to the coast in the outlet of the Reydarfjord, shows a very low salinity (from 33·95 ‰ in the surface to 34·32 ‰ at the bottom), and the temperature is comparatively high, because this whole water layer has been subject to a more or less great influence from the atmosphere.

The weakly saliferous water layer has a considerably lesser specific gravity than the more saliferous water towards the eastern part, and so it will act as a surface current away from the shore; that such a movement really takes place will be seen from the course of the isohalines 34·25 ‰ and 34·60 ‰, and the salinity in the surface varies rather comparatively with the distance from the shore. Further we have statements of the fact that the surface current a little way from the coast sets towards the east (C. Ryder: l. c.). Along the bottom we have probably a compensation current towards the shore. The course of the 1° isotherm gives a feeble suggestion of such a one.

This considerable change of the hydrographic conditions in this section since May consequently arises from the fact that the supply of river water had not yet been very great in May.

[1]) C. Ryder: Nogle Undersøgelser over Havstrømmene i Farvandene mellem Norge, Skotland og Grønland. Naut. met. Aarb. 1901. Kjøbenhavn 1902.

Discussion of the Surface Maps.

The surface temperature in August is on an average 3° higher than in May, especially in the eastern part of the research range, while the rise of temperature since May is less in the western part. In May the temperature was rising towards the west, the contrary is seen to have been the case in August.

The salinity varies pretty much but is on the whole uncommonly low within the whole district examined. The 35·00 ‰ isohaline has a most irregular course, and at several places there will probably be isolated areas with a salinity below 35·00 ‰. Still in drawing the 35 ‰ isohaline as well as possible we tried to give this isohaline a continuous course. We must call attention to two tongues of weakly saliferous water which stretch towards the south, one at 8°—9° west longitude, the other along the coast of Iceland. The eastern one evidently consists of water from the polar current; the upper layer of the latter which is very deficient of salt has in this season a less specific gravity than the Atlantic water (compare M. Knudsen: The Danish Ingolf-Expedition), and so it will be inclined to flow across it. This salt wanting surface layer is accordingly seen to rest on Atlantic water of about standard salinity, and is partly by the latter and partly by the atmosphere warmed up to about the same temperature as the Atlantic water. Station 5 A, however, shows mere polar water, from which we see that this distribution in the surface in the northern part of the mentioned tongue of the polar current has been accompanied by a distribution in the deep, so that the Atlantic water has completely disappeared from this place.

The low salinity near Iceland may arise either from the river water from Iceland itself or from the Arctic water. It is, however, reasonable to suppose that both factors assert themselves. In drawing the map, attention has been paid to some observations from the midst of July stretching from the Ingolfshöfde about 40 miles in southeastern direction and then towards the northeast, parallel with the coast. According to these observations the surface temperature was 10°—11°, but it sank to about 5° at 64° north latitude. By this sudden spring the limit is found between the warm Atlantic water and the Arctic water which is moving towards the south along the eastern coast of Iceland. The warm Atlantic water thus washes the southcoast of Iceland as far as to the Ingolfshöfde or the Hornefjord, then leaves the coast and moves in east-northeastern direction. A reaction current of cold water goes from the north down the coast, and to judge from the low temperature these waters do not remain long at this place but are torn away by the Atlantic current towards the east, and its influence on it is especially traced in the surface layer where it has a perceptible influence on the temperature and especially on the salinity. We have, however, a low salinity much farther towards the south than where the Arctic water may be supposed to assert itself. Now during the summer there is a considerable supply of fresh water from the rivers, and this fresh water will on account of its low specific gravity flow out over the ocean water. We have got proof for the fact that the surface current in summer is going from the shore, in the circumstance that the fry, bred on the shore banks in summer, is driving to sea [1]). This fresh water will not influence the surface temperature perceptibly. For if we have a certain volume of ocean water of a salinity of 35·25 ‰, it will assume a salinity of 35·00 ‰ by the mixture with $^1/_{140}$ of its volume of fresh water but so little a deal will, practically speaking, not change its temperature. But if we have 1 volume of Arctic water with a salinity of 34·50 ‰ and a temperature of 6°, it will by mixing with 2 volumes of Atlantic water of a salinity of 35·25 ‰ and a temperature of 9° C. give a mixture with a salinity of about 35·00 ‰ and a temperature of 8°.

The sudden spring in the temperature between the Hornefjord and the Ingolfshöfde shows that the Arctic water does not as such reach farther towards the south, and that the limit between the latter

[1]) Compare Dr. Hjort: Fiskeri og Hvalfangst i det nordlige Norge. Bergen 1902.

and the Atlantic water is rather sharp. This does not agree very well with the common view that the whole of Iceland is surrounded by a coast current in anticyclonical direction and with a considerable speed. For such a closed current circle must as to hydrography offer continuous transitions and not as here show a sudden spring in the physical quality of the water. Squarely on the direction of the current we must on the contrary expect rather strong variations, as this current is said to have a slight breadth, but east as well as south of Iceland (the quarterly measurings in May Section VI, a series of surface samples of the Seydisfjord in east-northeastern direction, from the Ingolfshöfde towards the southeast, and a section from the Vestman islands in southern direction) the variations were most regular and sometimes imperceptible.

Along the westcoast of Iceland we have this direction of current in the northgoing Irminger current which, at any rate in the summer, is continued towards the east along the northcoast, and at the eastern part of the latter we have also an eastgoing movement of the East-Icelandic polar current which having passed Langanes becomes southgoing along the eastern coast. As to the west-, north- and eastcoast we may so far speak of such a coast current as we have chiefly this direction of current in the surrounding seas. But in hydrographical respects there is nothing which indicates a westgoing current along the southcoast. For such a one must — as a continuation of the polar current along the eastcoast — at any rate in its eastern part have a low temperature and salinity and only gradually be mixed with the warm Atlantic water.

The East-Icelandic polar current is mostly free from ice, but it happens not seldom that even rather considerable masses of ice block up the east coast of Iceland, but only very seldom the ice reaches south of the Ingolfshöfde, and only quite exceptionally it reaches the Vestman islands. To take this drift of ice for an absolute proof of the presence of such a current is not permissible as the ice offers a much larger flat than the water to the influence of the wind, and the mere wind may possibly have carried it down to the south coast without the Arctic water, in which it was originally found, having been carried along so far. Thus we often find icebergs far away in the Atlantic ocean on far more southern shores, which have been carried away by the wind. It is, however, striking that ice is not more frequently found near the south of Iceland, if a westgoing current along the coast was in existence, for even if it is by degrees mixed with warm water and the washing out of the ice grows intenser, larger masses of ice would move a long way before they were quite melted.

For a period of 22 years (1877—92 and 1897—1902) the ice thus during four years (partly 1898) reached the Berufjord, during 2 years the Ingolfshöfde and during the years 1881 and 1888 it reached along the south coast the Vestman islands or the Ørebak Bay. In 1902 the ice at the east land sent some spurs down to the Vestman islands. For this year it has, however, been stated, that at the time when ice was found by the southcoast (April), continuous northeast, east- and southeast winds [1]) were prevailing, and it is very probable that these winds have been the most essential cause of the ice appearing by the southern land. By the southeast coast the limit between the warm and cold water was very sharp; thus for instance from the mailsteamer „Vesta“ at a distance of 5—8 miles from the coast water samples were taken from both the ship's sides with a difference of temperature of 5°—6° [2]). As mentioned above such a limit, however, is very seldom found, and probably the coast current, at any rate as to the south of Iceland, is not a constant phenomenon, but it juts shorter or longer to the west according to the prevailing conditions of wind. Thus the current bottles landed on the southeast and the south coast of Iceland now indicate such a coast current, and then they seem to indicate the opposite direction. The drift of the current bottles of the Nathorst-Expedition stated by Filip Åkerblom [3]) may as to the bottles landed on the south

[1]) V. Garde: Isforhold i de arktiske Have 1902. Naut. met. Aarbog 1902.

[2]) V. Garde: l. c.

[3]) Filip Åkerblom: Recherches océanographiques. Exp. de M. A.-G. Nathorst en 1899. Upps. Univ. Årssk. 1903. Further C. Ryder: Nogle Undersøgelser over Havstrømmene etc.

coast of Iceland very well have been another, for the bottles thrown out by the coast of Greenland may have followed the East-Greenlandic polar current and moved towards the east in the Denmark Strait. As none of them landed on the range from the Skagestrand Bay to the Ingolfshöfde, nothing can prove that they have gone east round the country, and that they have followed the East-Greenlandic polar current is much more probable, when we observe that those which have landed farthest towards the west give a much greater mean speed than the eastmost ones and have further landed long before them. No. 201 which was thrown out at the same place as No. 202, has passed near by Cape Nord and landed in the Skagestrand Bay. Of the bottles thrown out at about 70° north latitude and 12°—15° longitude one landed in the Skagestrand Bay, another near Cape Nord, and thus it is probable that part of them have passed by Cape Nord towards the south in the Denmark Strait and then have been carried back to the southcoast of Iceland by the Atlantic current. Some of them which have landed on the north coast show a great mean speed, till 6·8 miles in twenty four hours, while for the southern land it rarely surpasses 2·5 miles. This also seems to indicate that they have passed a much longer way through the Denmark Strait.

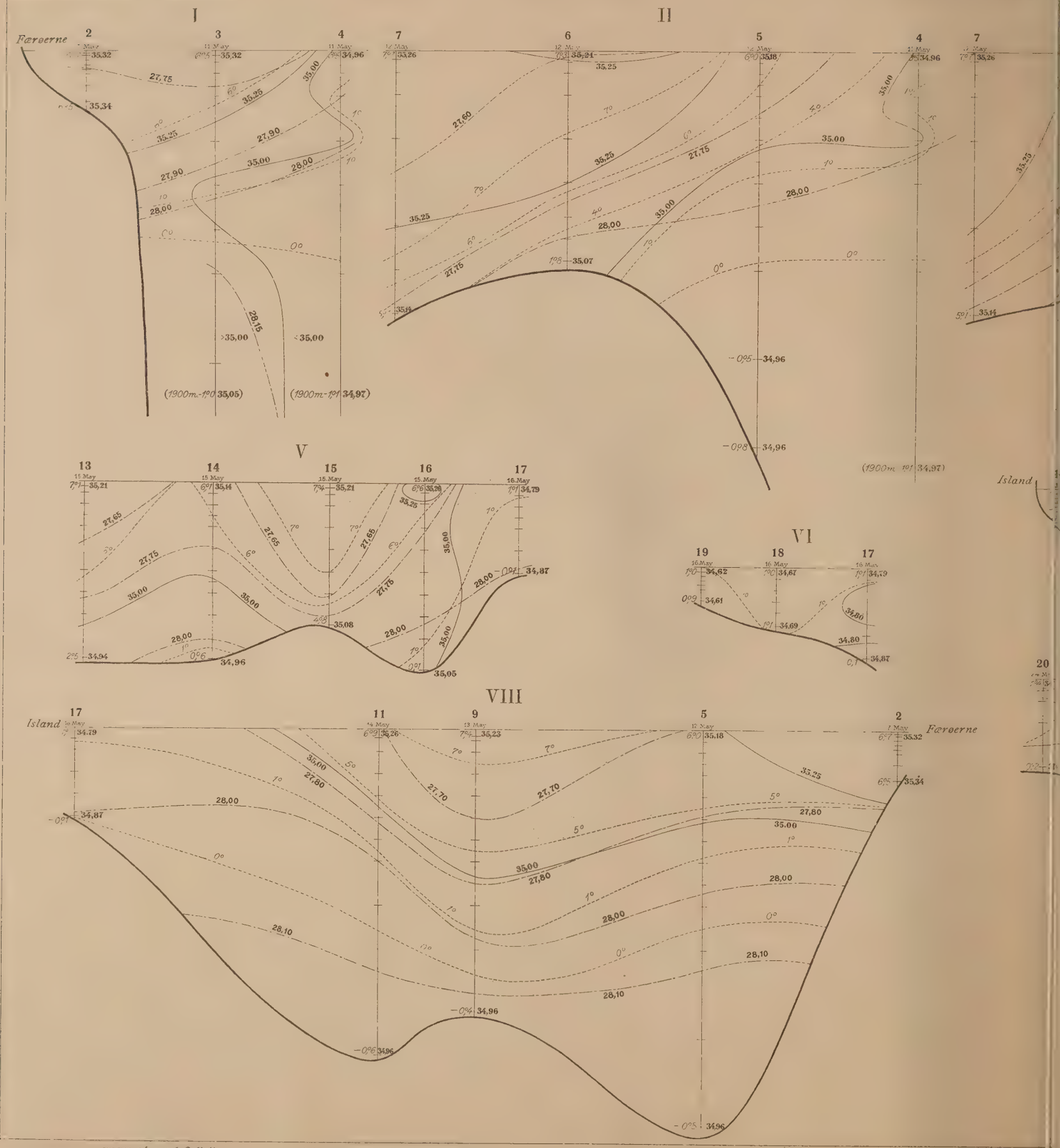
Such a division of the bottles thrown out north of Iceland is not improbable. When the ice appears near the north of Iceland it generally comes to the whole coast [1]) at the same time, and it must then have moved in southern direction; when it reaches Iceland it divides, one part goes to the east and another probably to the west round the island; it must indeed be remembered that the eastern branch of the Irminger current is an under-current [2]) and may probably by a great supply from the polar current disappear almost totally. That such a westgoing current may appear at the western part of the north coast of Iceland is proved by some of the current bottles mentioned by C. Ryder [3]).

[1]) C. Ryder: Isforholdene i Nordhavet 1877—92, Tidsskrift for Søvæsen. 1896.
[2]) Martin Knudsen: The Danish Ingolf-Expedition.
[3]) C. Ryder: Nogle Undersøgelser over Havstrømmene i Farvandene mellem Norge, Skotland og Grønland, Nautisk met. Aarbog 1901.

TO BE ADDED.

In Table II, p. 8, is to be added a surface sample which was taken on the 4th of June at 63°21′ N. Lat. 19°05′ W. Long. with temperature 7°96, salinity 34·97 ‰.

GREENLAND
ICELAND
SCOTLAND
1
2
3
4
4A
4B
4C
4D
4E
4F
5
5A
6
7
7A
7B
8 May
8 Aug
10 May
10 Aug
10A
9
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
XIII
XIV

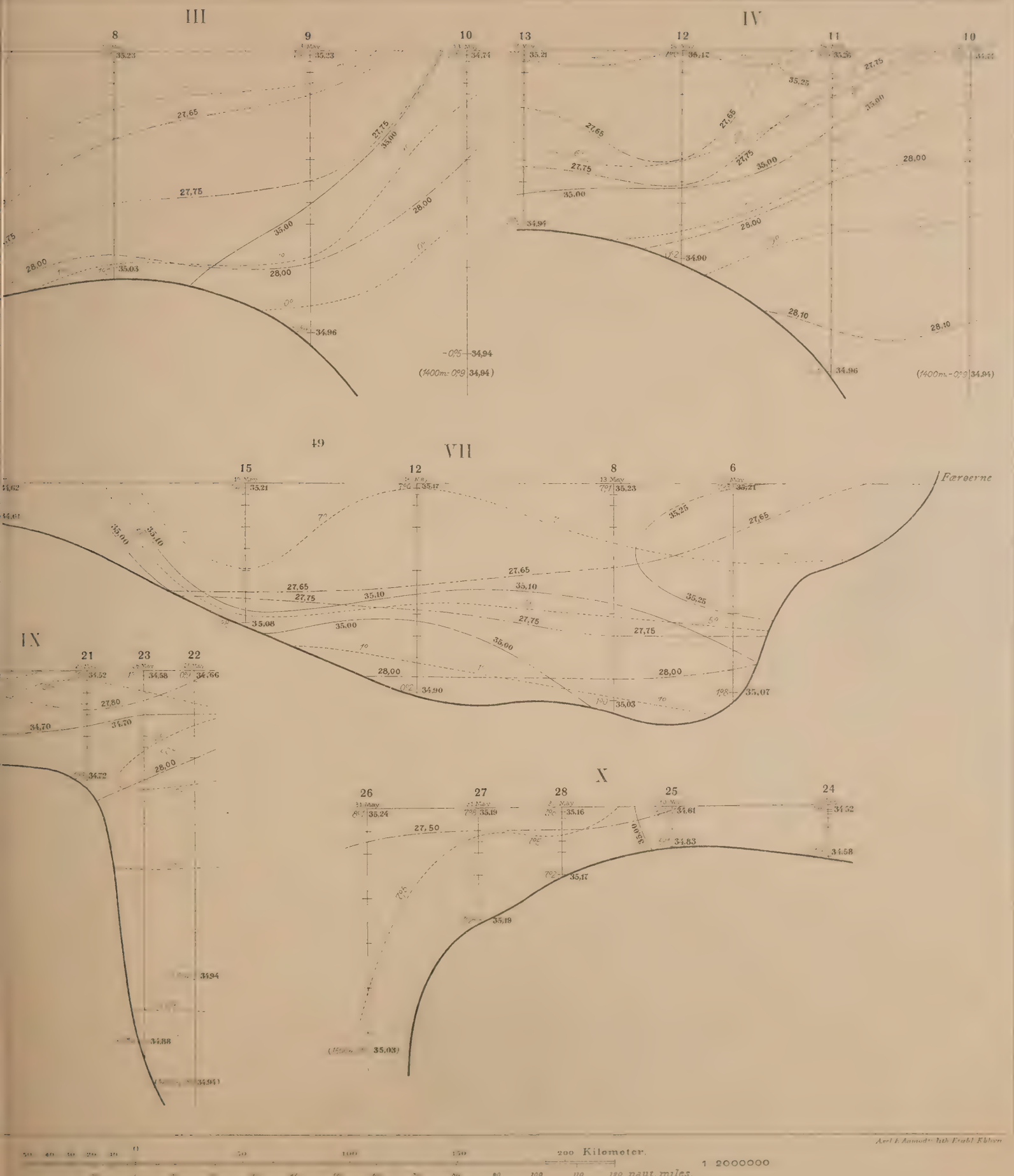


curves of equal Salinity.
curves of equal Temperature.
curves of equal σ_t

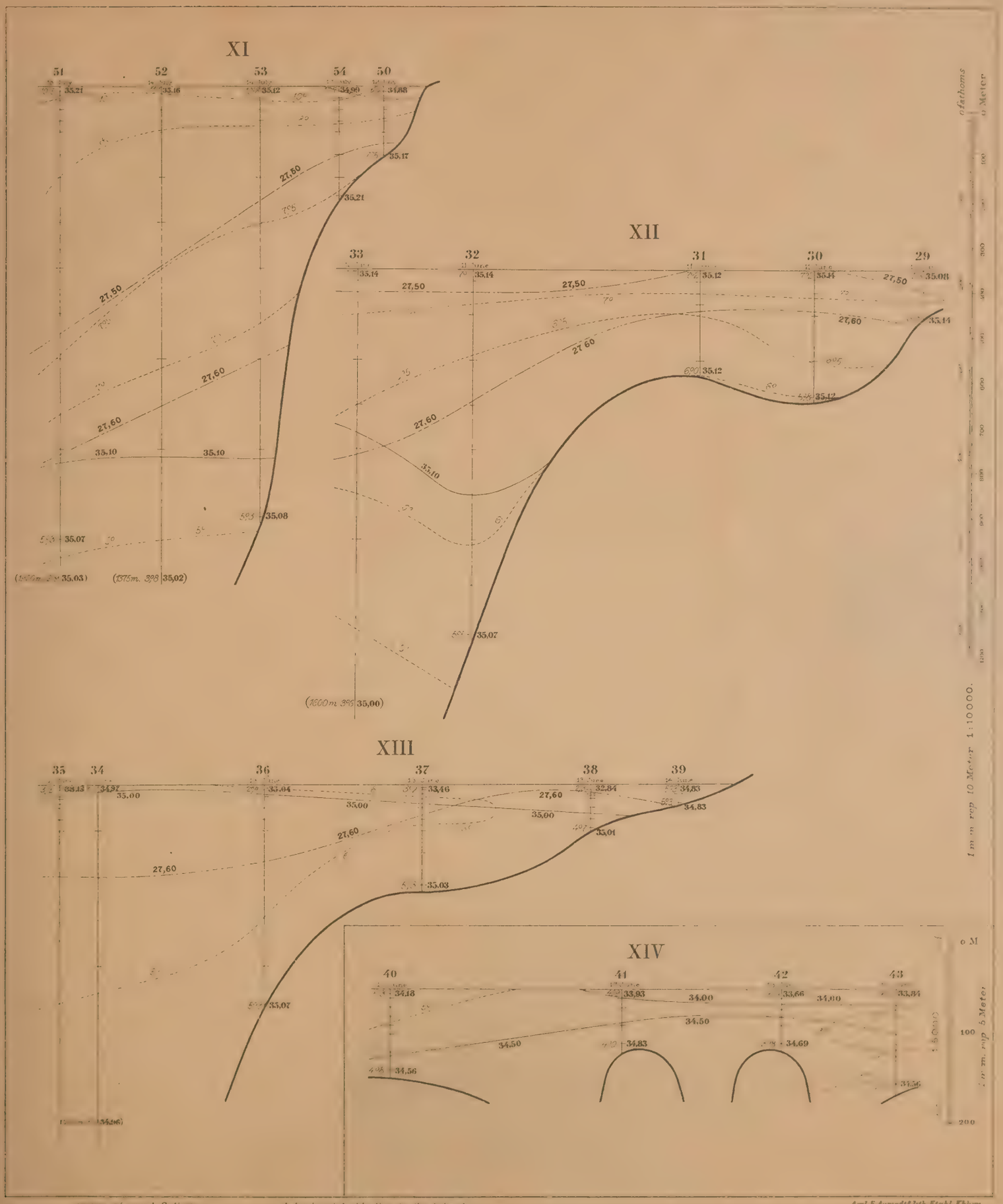
A horizontal side line to the left of a vertical line at a station, represents an observation of temperature; one to the right an observation of salinity.

1mm rep 2 Kilomet

May 1903.


III
IV
VII
IX
X
Færoerne
27,65
27,75
35,00
28,00
35,10
35,25
34,96
34,94
34,90
35,03
35,07
35,08
35,17
35,19
35,24
34,83
34,61
34,58
34,52
34,70
34,80
27,50
200 Kilometer.
1 2000000
100 naut. miles.

Sections in June and July 1903.



——— curves of equal Salinity.
. . . . . curves of equal Temperature.
— — curves of equals.

A horizontal side line to the left of a vertical line at a station, represents an observation of temperature, one to the right an observation of salinity.

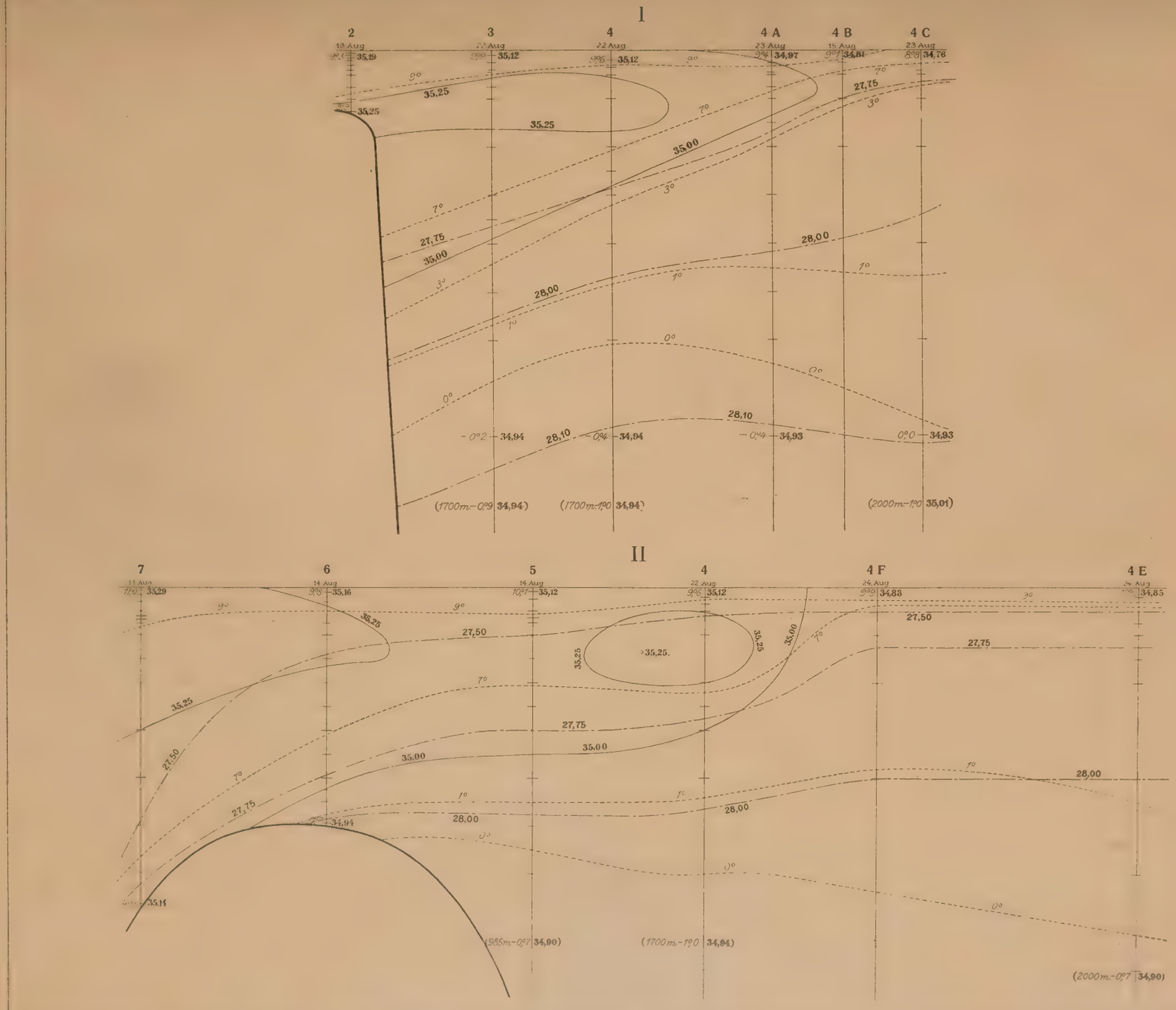
Axel E. Aumodt's lith. Etabl. Kbhvn

1 m m. rep. 2 Kilometer.

Kilometer
10 0 10 20 30 40 50 60 70 80 90 100 110
10 0 10 20 30 40 50 60
naut. miles

1:2000000

Sections in August 1903.



1 mm rep 10 Meter 1:10000.

fathoms 0 Meter

curves of equal Salinity.
curves of equal Temperature.
curves of equal σ_t

A horizontal side line to the left of a vertical line at a station, represents an observation of temperature; one to the right an observation of salinity.

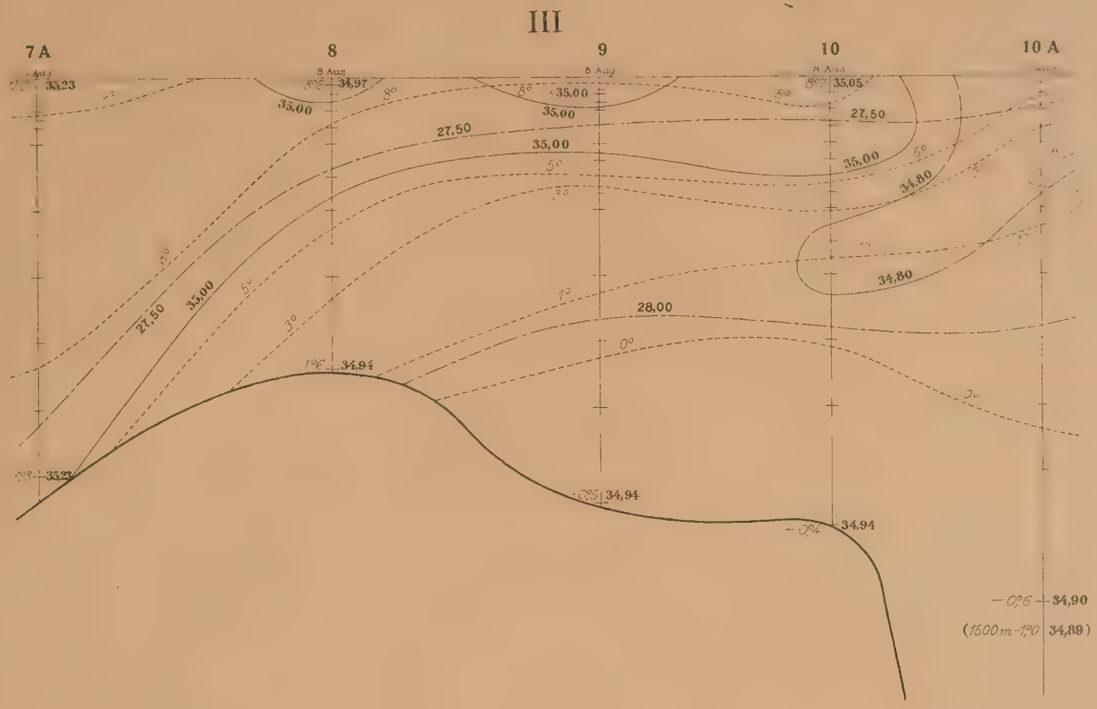
1mm. rep. 2 Kilometer.

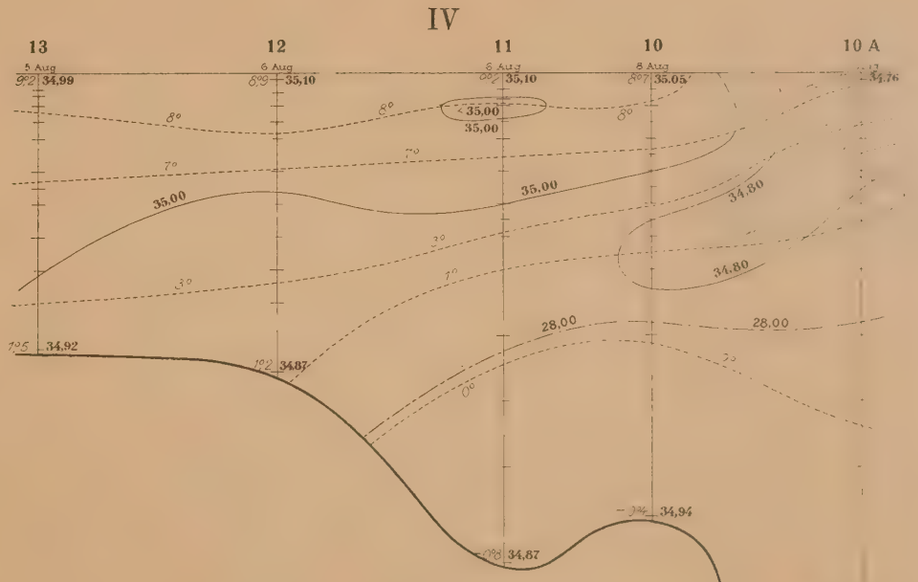
Kilometer

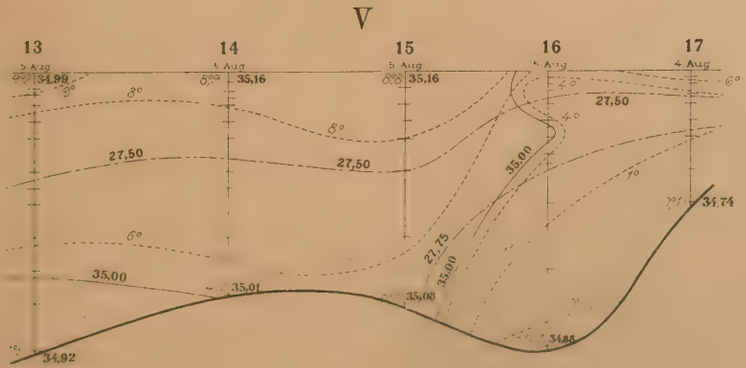
1 : 2000000

Axel F. Aumodt's lith. Etabl. Kiöbenh.

Sections in August 1903.







curves of equal Salinity.
curves of equal Temperature.
curves of equal σt

A horizontal side line to the left of a vertical line at a station, represents an observation of temperature; one to the right an observation of salinity.

Axel E. Aamodt & Joh. Etabl. Kihver

1 mm. rep. 2 Kilometer.

Kilometer

20 0 10 20 30 40 50 60 70 80 90 100 110

10 0 10 20 30 40 50 60

naut. miles.

1:2000000

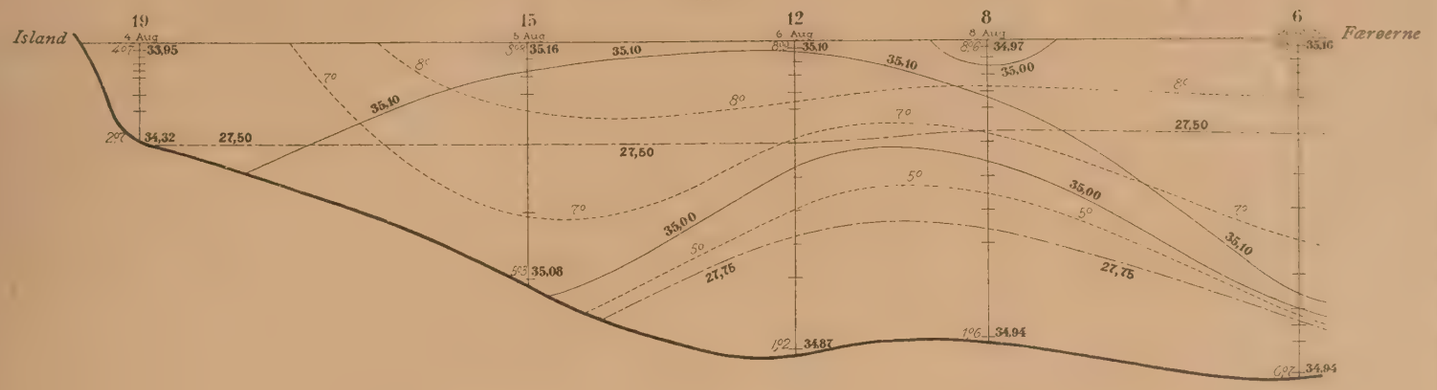
1 m. rep. 10 Meter. 1:10000.

Fathoms 0 Meter

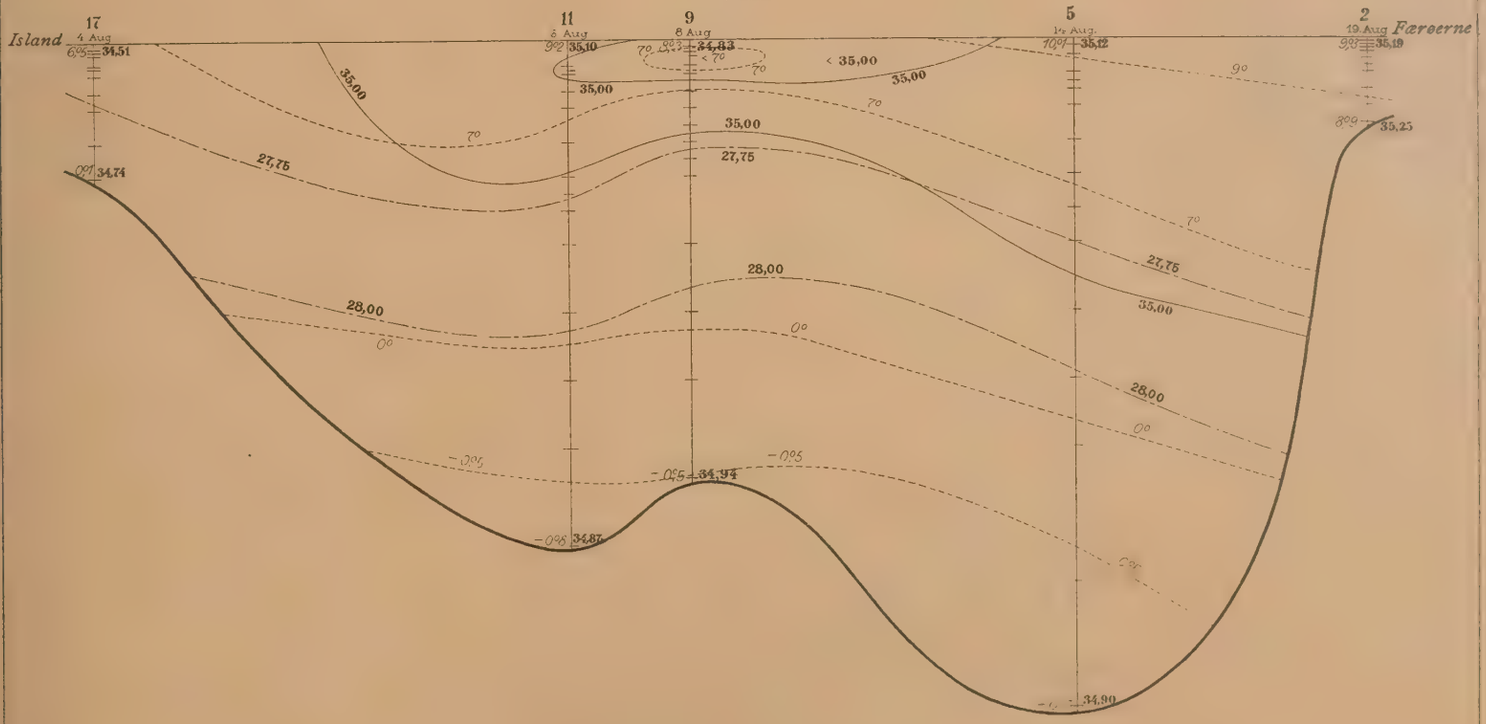
Sections in August 1903.

Medd. fra Kom. for Havunders. Serie: Hydrografi Bd. I Nr. 4 Pl. VI.

VII



VIII



fathoms 0 Meter

1 mm rep 10 Meter. 1 : 10000.

curves of equal Salinity.
curves of equal Temperature.
curves of equal σt

A horizontal side line to the left of a vertical line at a station, represents an observation of temperature; one to the right an observation of salinity.

Aml. K. Aamodt's lith. Etabl. Kbhvn.

1 mm. rep. 2 Kilometer.

Kilometer

10 0 10 20 30 40 50 60 70 80 90 100 110

10 0 10 20 30 40 50 60

naut. miles.

1:2000000

Surface-map May 1903

——— Curves of equal Salinity

– – – – – – – Curves of equal Temperature

1 : 5 000 000

Surface-map August 1903

Curves of equal Salinity

Curves of equal Temperature

MEDDELELSER FRA KOMMISSIONEN FOR HAVUNDERSØGELSER
SERIE: HYDROGRAFI · BIND I · NR. 5 · 1904

ON THE DETERMINATION OF OXYGEN IN SEA-WATER

BY

NIELS BJERRUM

KØBENHAVN
I KOMMISSION HOS C. A. REITZEL
BIANCO LUNOS BOGTRYKKERI
1904

Introduction.

All the many analyses of air in sea-water which have during the last decades been made by hydrographic examinations have suffered from the fact that it was almost impossible to get exact determinations on board a ship, while on the other hand water samples by being kept until one got a shore very often altered their contents of oxygen. As a perfect analysis of air from a watersample was thus a very circumstantial thing when a suitable exactness was demanded, it was difficult to have a sufficiently great number of them made.

So it was to be supposed that it might be of interest, instead of making a perfect analysis of air, to be contented with making a determination of oxygen by one of the chemical methods of titration which are worked up for the use of the examination of drinking water.

Such a determination might be made both quickly and exactly. On the other hand neither the nitrogen nor the carbonic acid was determined. But as oxygen is the kind of air the quantity of which is subject to the greatest variations, and which is at the same time of the greatest importance to the organisms, a separate examination of its presence might be supposed to be of rather a considerable value.

On the Pola-expedition in 1890 Natterer[1]) for the first time introduced such determinations of oxygen in hydrographic researches. He determined the quantity of oxygen in water by the method which L. W. Winkler[2]) has worked up, and which consists in adding to the watersample solutions of manganese chloride and caustic soda (the latter solution contains potassium iodide for the sake of the later treatment) and thus producing a sediment of manganous hydroxide, which almost immediately combines with the oxygen in presence, forming manganic hydroxide. When then the liquid is acidified with hydrochloric acid the hydroxides are dissolved and a quantity of iodine is set free, which is equivalent to the quantity of oxygen formerly present, and which is determined by a titration with a solution of sodium thiosulphate.

Natterer undertook all these researches on board, and as a chemical laboratory had been established on board, it was not a very difficult work. But in many cases, for instance in the Danish quarterly researches, which are made with ships that only are used a few days every time, the conditions on board are more primitive. So it would be of great importance if it was possible to divide the work of the analysis in two parts so that only the most necessary work was undertaken on board while the rest was made on shore.

I have tried to ascertain whether, without getting wrong results, we might wait with undertaking the titration till we came on shore, if only on board we added to the watersamples the solutions of manganous chloride and caustic soda containing iodide of potassium

It is, a priori, improbable that the chemical processes, which often alter the contents of oxygen of watersamples, should take place during a long keeping, when all the oxygen by adding the reagents has been bound to manganous hydroxide. And by keeping the bottles in which the watersample is under water we may guard against the watersample being fouled by atmospherical air through leaks at the stopper.

[1]) Denkschriften d. kais. Akad. d. Wiss. Band 54 (1892).

[2]) Berichte d. deutschen chem. Ges. Band 21. p. 2834; Band 22. p. 1764.

The researches I have made in order to examine the effects of a keeping, the reagents having been added, have also given the following satisfactory results.

First some watersamples from the harbours of Copenhagen (No. 1 and No. 2) were examined. When the contents of oxygen were determined at once, we found in watersample No. 1 6·79 cc. of oxygen and in watersample No. 2 7·25 cc. in the liter. The volume of the oxygen in these indications, as also in the following ones, is reduced to 0° Cels. and 760^{mm} pressure. When the samples were kept for a fortnight, the reagents having been added, No. 1 still contained 6·72 cc. and No. 2 7·24 cc. of oxygen. But the contents of oxygen, after a keeping of a fortnight without the addition of reagents fell to 4·65 cc. in No. 1 and 6·38 cc. in No. 2. Thus with reagents the contents of oxygen during a fortnight decreased 0·07 cc. in No. 1 and 0·01 cc. in No. 2, while the contents of oxygen without any addition of reagents decreased respectively 2·34 cc. and 0·87 cc. during the same time.

In January 1904 a series of uniform water-samples were taken in the Sound off Hellerup, and to all the samples was immediately added manganous chloride and iodide of potassium. The four water-samples which were then at once examined gave the following contents of oxygen:

9·10 9·06 9·06 8·94. Mean number: 9·040; mean error: 0·070.

While three other samples which were analyzed 22 days later gave:

9·13 9·03 9·01. Mean number: 9·057; mean error: 0·064.

An equal series of water-samples were taken in the harbour of Copenhagen in the beginning of the month of June; six of these were analyzed the next day, and the following contents of oxygen were found:

7·76 7·72 7·72 7·68 7·71 7·73. Mean number: 7·72; mean error: 0·026.

In two which were analyzed two weeks later were found:

7·71 7·76. Mean number: 7·735; mean error: 0·036.

And in four which were analyzed four weeks later were found:

7·72 7·68 7·69 7·74. Mean number: 7·707; mean error: 0·027.

After these experiments it must be supposed that we may very well suffer several weeks to elapse before we add the hydrochloric acid and titrate the samples. And this method was used in the analyses of oxygen which are described in the following.

Some experiments which I made to form a colorimetric method for the determination of oxygen in seawater gave bad results. It is, indeed, rather decisive for the inefficiency of colorimetric methods here that reliable colorimetric analyses demand perfectly clear liquids; for this condition is rarely found in seawater.

In the Danish hydrographic quarterly researches in November 1903 and in February and May 1904 I had an opportunity of making a few greater series of determinations of oxygen in seawater. The details of these analyses were the following.

Method of analysis.

When the heat insulating water-bottle, which, unfortunately, could only hold half a liter, had come up, and the temperature had been read, a few cc. of water were allowed to run out. Then the spout of the water-bottle was by means of a thickwalled indiarubber tube connected with a glass-tube which was 4^{mm} wide inside, and which through an indiarubber stopper with two holes went down to the bottom of the bottle which was intended for the keeping of the sample. This bottle was provided with a glass-stopper, well ground for the purpose, and held about 150 cc. It had a pretty wide neck —

about 20mm broad at the top. Both the stopper and the bottle were numbered to prevent a mistake. The indiarubber stopper must be so large that it only reaches a few millimetres down the neck of the bottle, else there will be too little water in the bottle so that we cannot afterwards put in the glass-stopper without an air-bubble remaining in the bottle. The glass-stopper must not be hollow beneath or, which is often the case, have a little hollow room which is in connection with the surroundings through a narrow canal.

Through the other hole in the indiarubber stopper a twice bowed tube was passing, the short branch of which was put so far down in the stopper that it was near projecting, which it did not, however, do. The other branch of the glass-tube ended in a bottle of about 150 cc., which was only used to measure how much had been allowed to run through the first bottle. The two bottles were held in one hand (the horizontal piece of the glass-tube as short as possible), with the other hand the stopcock of the water-bottle was opened; the first bottle was filled with a stream of water, not too fast, and then so much water was made to run through it that the other bottle was nearly filled. The 200 cc. of water which were still left in the water-bottle were used for the water-sample for the determination of chlorine.

The bottle was filled with surface water by dipping it into a pail of water which had just been taken up.

Immediately when the bottle had been filled and the indiarubber stopper taken off, 1 cc. of soda-lye containing iodide of potassium and 1/2 cc. of manganous chloride were carefully placed on the bottom of it by means of thin-stemmed pipettes. Then the glass-stopper was carefully put in so that no airbubble remained in the bottle and fastened with a brass wire clam. As soon as the solution of manganous chloride and the soda-lye are mixed together a white sediment is formed which eagerly absorbs oxygen and is dyed brown by it. It will be seen how cautious we must be in adding these fluids in order to avoid errors.

Having been well shaken the bottle was placed in a box of zink-plate filled with sea-water. The box was provided with a pretty closely fitting lid, and it was 3 cm. higher than it need be to hold the bottle, so that the bottle continued being covered with water even if some of the water should run out during the transport. The zinc-plate boxes, however, were excellently tight when only they were not placed on the sides[1]).

The soda-lye was made by dissolving 36 grammes of caustic soda e natrio (Merck's preparation) and 10 grammes of iodide of potassium in so much distilled water that the solution filled 100 cc. The solution of manganous chloride contained 40 grammes of $Mn\,Cl_2\,.\,4\,H_2O$ in 100 cc.; and to prevent a possible fouling with a little alkali from causing the solution to precipitate a sediment and to absorb oxygen two cc. of strong hydrochloric acid were added to the 100 cc.

None of the solutions was coloured blue by a solution of starch immediately after having been acidified, and as to the manganous chloride, after adding iodide of potassium, when we took fivefold of what had been used for an analysis of oxygen and diluted till a value of about 150 cc. This test the solutions must always be able to stand. It proves that the solution of caustic soda does not contain nitrous acid and the solution of manganous chloride no iron, at any rate not so much that it can alter the result of the analysis.

The test-bottles were kept in a box where also the many pipettes which were to be used (two for each test) were placed in paste board cases with 10 in each. In the same box there was room for the used pipettes and further a room covered with zinc in which the bottle was placed while the reagents were added, and when the stopper was put in. During this work 1 1/2 cc. of fluid are running out of the bottle.

When the box with the bottles had arrived at the hydrographic laboratory the proper chemical analysis was undertaken. First the sediment in the bottles was suffered to precipitate and then 2 cc. of about 30% hydrochloric acid were placed on the bottom of the bottles by means of a thin-stemmed

[1]) In the latest time after proposal of Docent M. Knudsen cylindrical glass-vessels closed with cork-stoppers are used instead of the zinc-boxes, which were strongly attacked by the sea-water.

pipette. We may for a short time remove the stopper from the bottle when the sediment has settled, as it is only the sediment which absorbs oxygen. After some time of repeated shaking the sediment was dissolved. The fluid was then cautiously poured into a beaker and titrated with a thin solution of thiosulphate, which was added from a burette of 30 cc., till the yellow iodine colour had become feeble, and then after adding some cc. of solution of starch, until the blue colour disappeared. The bottle was rinsed with some of the discoloured solution which then assumed a bluish colour and this was made to disappear by a superaddition of some drops of a solution of thiosulphate.

The solution of thiosulphate was produced by dissolving 8 or 10 grammes of thiosulphate of sodium in 4 liters of water and letting this stand for a week. Its strength was determined by weighing with great exactness about 0·4 grammes of acid potassium iodate (potassium biiodate), and dissolving it in water in a measuring bottle, which held $^1/_2$ liter. Of this solution, which keeps unchanged for a rather long time, and which, therefore, only rarely need be produced again, 10 cc. were pipetted into a mixture of 150 cc. of water, 5 cc. 10 % solution of iodide of potassium and 2 cc. of strong hydrochloric acid, whereon the disengaged iodine was titrated with the solution of thiosulphate.

If a grammes of potassium biiodate are weighed and we apply b cc. of thiosulphate, 1 cc. of solution of thiosulphate will answer to:

$$\frac{a}{b} \cdot \frac{10 + x}{500 + y} \cdot 172,3 \text{ cc. of oxygen at } 0^\circ \text{ C. and } 760^{mm}$$

(x and y being the corrections on the pipette and the measuring bottle).

It will, however, be necessary once for all to let a chemist determine the degree of effect of the acid potassium iodate which is used. The preparations now in market are generally far from pure.

The determinations of the strength of the solution of thiosulphate must be made anew every day of an analysis, as the solution does not keep unchanged for a longer period. The solution must be kept in a dark and cool place.

The solution of starch may be produced by heating about $^1/_2$ gramm of starch with 250 cc. of water until boiling, boiling it for 5 minutes, then cooling it, and then, after suffering it to stand, decanting from the sediment and keeping it in a closed bottle. But it is made in the easiest way of dissoluble starch which only need be suspended in water and heated until boiling. The solution of starch is not very durable. It is only good when 2 cc. of it added to 150 cc. of a mild acid solution of iodide of potassium, which contains a very little iodine, gives a sharp transition without red shades from blue to colourless by dripping drops of solution of thiosulphate into it.

Further, in the laboratory by weighing the bottles, partly empty and partly filled with distilled water, with the exactness of $^1/_{10}$ gramme we had to determine their volume, consequently how much seawater had been analyzed. Properly speaking $1^1/_2$ cc. less were analysed. But for this no allowance was made in the calculation of the analysis because they added reagents also contained oxygen.

Determinations.

The results of the determinations of oxygen which were made by this method in November 1903 and in February and May 1904 together with the undertaking of the usual quarterly measures are stated in the following tables.

As to the situation of the stations, the time, when they were examined, the conditions of weather, and other circumstances we refer to: Bulletin publié par le bureau du conseil permanent international pour l'exploration de la mer. Année 1903—1904.

Table I. Determinations made on water-samples taken from $^1/_{11}$—$^3/_{11}$ 1903 in the Kattegat.

Station Da 15. $^1/_{11}$ 8h 15 a. m. Barometer 763·3 mm. Temperature of the air 8·8° Cels.						Station Da 18. $^1/_{11}$ 3h 45 p. m. Barometer 765·2 mm. Temperature of the air 8·4° Cels.						Station Da 20. $^1/_{11}$, 7h 55 p. m. Barometer 766·8 mm. Temperature of the air 8·8° Cels.						Station Da 21. $^2/_{11}$, 12h 05 a. m. Barometer 768 mm. Temperature of the air 8·7° Cels.					
Depth in M.	Temp. in ° Cels.	Salinity in °/₀₀	Cc. of oxygen in 1 liter	Remarks on the[1]) plancton		Depth in M.	Temp. in ° Cels.	Salinity in °/₀₀	Cc. of oxygen in 1 liter	Remarks on the plancton		Depth in M.	Temp. in ° Cels.	Salinity in °/₀₀	Cc. of oxygen in 1 liter	Remarks on the plancton		Depth in M.	Temp. in ° Cels.	Salinity in °/₀₀	Cc. of oxygen in 1 liter	Remarks on the plancton	
				amount	kind					amount	kind					amount	kind					amount	kind
0	8·7	20·61	7·18	very great	plants predominant over animals	0	8·6	18·39	6·72	very great	plants predominant over animals	0	8·64	18·31	7·38	very great	plants predominant over animals	0	8·9	16·44	7·27	very great	plants predominant over animals
			7·17			5	8·62	18·39	7·36						7·37			5	9·23	17·16	7·25		
5	8·68	20·77	7·10			10	9·12	20·50	6·98			5	8·64	18·31	7·34			10	9·20	18·59	7·12		
10	8·68	20·90	7·11			15	10·20	26·91	5·74			10	8·82	19·74	7·22			15	10·32	33·78	5·04		
15	8·85	21·51	6·99			20	10·72	32·66	5·65						7·14			20	10·12	33·98	5·04		
20	9·96	31·42	6·59			30	10·94	33·28	5·36			15	8·72	20·05	7·20			30	9·98	34·07	5·00		
30	10·16	33·37	5·78			41	11·14	33·64	5·26			20	10·50	32·94	5·51								
40	9·80	33·96	5·59									28	10·86	34·05	4·95								
50	9·37	34·34	5·45																				
60	9·10	34·49	5·47																				

[1]) The determinations of plancton Mr. Docent OSTENFELD has been so kind as to communicate to me in the form stated here. The scale used in the indications of amount is: very little, little, not quite little, not great, middle great, pretty great, very great.

Table II. Determinations made on water-samples taken $^2/_3$ 1904 in the Kattegat.

Station Da 15. $^2/_2$ 11h 55 a. m. Barometer 759 mm. Temperature of the air ÷ 0·5°						Station Da 18. $^2/_2$ 9h 30 p. m. Barometer 756 mm. Temperature of the air ÷ 1°						Station Da 20. $^3/_2$ 3h 05 a. m. Barometer 754 mm. Temperature of the air ÷ 1°					
Depth in M.	Temp. in ° Cels.	Salinity in °/₀₀	Cc. of oxygen in 1 liter	Remarks on the plancton		Depth in M.	Temp. in ° Cels.	Salinity in °/₀₀	Cc. of oxygen in 1 liter	Remarks on the plancton		Depth in M.	Temp. in ° Cels.	Salinity in °/₀₀	Cc. of oxygen in 1 liter	Remarks on the plancton	
				amount	kind					amount	kind					amount	kind
0	1·6	21·76	6·44	little	animals a little (but only a little) predominant over plants	0	1·1	20·61	7·79	little	animals a little (but only a little) predominant over plants	0	1·2	18·60	7·76	little	animals a little (but only a little) predominant over plants
5	1·75	21·98	5·42			20	4·4	32·45	6·51			10	2·1	20·91	5·83		
10	1·95	22·88	7·77			40	5·0	33·21	6·31			15	3·5	23·51	7·33		
15	2·8	29·07	7·27									20	6·5	33·04	5·43		
40	3·45	32·12	7·18														
50	4·2	33·17	6·82														

Table III. Determinations of oxygen made on water-samples taken from $^1/_3$—$^2/_3$ 1904 in the Great Belt.

Station Da 23. $^1/_2$ 8h 15 a. m. Barometer 759 mm. Temperature of the air ÷ 1·2°						Station Da 26. $^1/_2$ 2h 15 p. m. Barometer 759 mm. Temperature of the air ÷ 1·3°						Station Da 29. $^2/_2$ 10h 30 a. m. Barometer 760 mm. Temperature of the air ÷ 1°						Station Da 32. $^2/_2$ 5h 00 p. m. Barometer 758 mm. Temperature of the air ÷ 1·5°					
Depth in M.	Temp. in ° Cels.	Salinity in °/₀₀	Cc. of oxygen in 1 liter	Remarks on the plancton		Depth in M.	Temp. in ° Cels.	Salinity in °/₀₀	Cc. of oxygen in 1 liter	Remarks on the plancton		Depth in M.	Temp. in ° Cels.	Salinity in °/₀₀	Cc. of oxygen in 1 liter	Remarks on the plancton		Depth in M.	Temp. in ° Cels.	Salinity in °/₀₀	Cc. of oxygen in 1 liter	Remarks on the plancton	
				amount	kind					amount	kind					amount	kind					amount	kind
0	2·5	21·08	5·94	very little	animals predominant	0	1·7	17·63	7·47	very little	animals predominant	0	1·5	15·14	6·81	very little	animals predominant	0	1·5	15·35	6·56	not quite little	animals predominant
20	3·3	24·70	6·97			10	1·8	17·70	7·53			10	1·6	15·50	5·89			10	1·6	15·44	5·79		
35	5·58	31·00	5·18			20	4·80	28·71	4·60			15	1·68	15·53	4·95			15	1·8	15·88	5·76		
						25	5·40	29·85	4·51			20	2·0	16·94	6·18			30	3·62	23·21	5·48		
						50	6·15	31·82	5·27			25	2·8	25·35	6·05								

Table IV. Determinations of oxygen made on water-samples taken from 1/5—2/5 1904 in the Skager Rak.

Station Da 4. 1/5 7h40 p. m. Barometer 763·5 mm. Temperature of the air 8·0°						Station Da 7. 2/5 4h00 a. m. Barometer 760 mm. Temperature of the air 7·5°						Station Da 9. 2/5 7h40 a. m. Barometer 758 mm. Temperature of the air 7·5°						Station Da 12. 2/5 1h50 p. m. Barometer 753 mm. Temperature of the air 8·5°					
Depth in M.	Temp. in ° Cels.	Salinity in ‰	Cc. of oxygen in 1 liter	Remarks on the plancton		Depth in M.	Temp. in ° Cels.	Salinity in ‰	Cc. of oxygen in 1 liter	Remarks on the plancton		Depth in M.	Temp. in ° Cels.	Salinity in ‰	Cc. of oxygen in 1 liter	Remarks on the plancton		Depth in M.	Temp. in ° Cels.	Salinity in ‰	Cc. of oxygen in 1 liter	Remarks on the plancton	
				amount	kind					amount	kind					amount	kind					amount	kind
0	6·6	30·75	6·97	not great	plants = animals	0	6·2	30·61	5·01	not great	plants = animals	0	6·9	27·25	4·85	middle great	plants < animals	0	7·5	28·33	5·27	pretty great	plants < animals
10	5·9	32·34	7·27			10	6·3	31·92	6·51			10	6·2	28·89	5·86			5	6·2	28·39	5·15		
15	5·6	32·39	6·47			20	5·3	32·74	6·20			15	6·05	30·91	5·35			10	6·1	28·98	6·58		
40	5·4	34·83	6·34			30	5·55	33·06	6·43			20	5·9	32·01	5·37			20	4·65	33·49	5·47		
50	5·2	34·85	6·57			40	5·5	33·15	6·53			30	5·8	32·34	5·10			40	4·1	33·95	4·43		
75	5·15	34·87	6·36			60	5·1	33·46	6·04			40	5·2	33·04	6·03								
100	5·15	34·87	5·37			80	3·95	34·27	5·92														
150	4·95	34·88	4·99																				
180	5·3	34·92	5·27																				

Table V. Determinations of oxygen made on water-samples taken from 1/5—2/5 1904 in the Kattegat.

Station Da 15. 1/5 11h45 a. m. Barometer 760 mm. Temperature of the air 10°						Station Da 18. 1/5 6h53 p. m. Barometer 759 mm. Temperature of the air 9°						Station Da 20. 1/5 11h40 p. m. Barometer 757·6 mm. Temperature of the air 7·5°						Station Da 21. 2/5 4h00 a. m. Barometer 754 mm. Temperature of the air 7°					
Depth in M.	Temp. in ° Cels.	Salinity in ‰	Cc. of oxygen in 1 liter	Remarks on the plancton		Depth in M.	Temp. in ° Cels.	Salinity in ‰	Cc. of oxygen in 1 liter	Remarks on the plancton		Depth in M.	Temp. in ° Cels.	Salinity in ‰	Cc. of oxygen in 1 liter	Remarks on the plancton		Depth in M.	Temp. in ° Cels.	Salinity in ‰	Cc. of oxygen in 1 liter	Remarks on the plancton	
				amount	kind					amount	kind					amount	kind					amount	kind
0	6·8	23·78	7·32	middle great	plants < animals	0	7·8	24·70	7·10	pretty great	plants < animals	0	8·2	19·96	7·09	pretty great	plants < animals	0	7·8	20·59	7·08	middle great	plants < animals
5	6·43	23·80	7·18			5	6·65	26·35	7·11			5	6·98	22·27	7·19			5	7·42	21·65	7·30		
10	6·43	23·80	7·17			10	6·60	26·91	6·95			10	6·04	24·00	7·38			7½	7·02	21·87	7·12		
15	6·00	24·36	7·37			15	5·32	29·11	7·33			15	5·38	27·56	7·39			10	6·40	22·72	7·31		
17	6·00	25·82	7·33			20	4·00	32·34	7·22			20	4·94	34·00	6·11			15	5·21	34·07	6·02		
20	4·48	29·14	7·35			30	3·90	33·62	6·79			28	5·02	34·29	5·66			20	5·14	34·27	6·02		
30	4·81	33·84	6·82			40	4·40	33·95	6·31									30	5·13	34·27	6·00		
40	3·98	34·00	6·97			43	4·46	34·13	6·04									34	5·12	34·27	5·97		
50	3·70	34·11	6·87																				
62	3·84	34·34	6·52																				

Table VI. Determinations of oxygen made on water-samples taken from 1/5—2/5 1904 in the Great Belt.

Station Da 23. 1/5 6h20 a. m. Barometer 765 mm. Temperature of the air 7·5°						Station Da 26. 1/5 11h00 a. m. Barometer 767 mm. Temperature of the air 11°						Station Da 29. 1/5 2h00 p. m. Barometer 767 mm. Temperature of the air 10°						Station Da 32. 1/5 6h35 p. m. Barometer 765 mm. Temperature of the air 8°					
Depth in M.	Temp. in ° Cels.	Salinity in ‰	Cc. of oxygen in 1 liter	Remarks on the plancton		Depth in M.	Temp. in ° Cels.	Salinity in ‰	Cc. of oxygen in 1 liter	Remarks on the plancton		Depth in M.	Temp. in ° Cels.	Salinity in ‰	Cc. of oxygen in 1 liter	Remarks on the plancton		Depth in M.	Temp. in ° Cels.	Salinity in ‰	Cc. of oxygen in 1 liter	Remarks on the plancton	
				amount	kind					amount	kind					amount	kind					amount	kind
0	7·5	19·20	4·33	not great	plants < animals	0	8·2	17·27	6·51	middle great	plants < animals	0	7·9	17·02	5·42	middle great	plants < animals	0	7·6	15·52	6·50	middle great	plants < animals
10	7·05	20·95	6·72			10	6·70	21·91	5·62			5	7·4	18·60	6·37			5	7·1	15·82	6·86		
15	5·55	30·52	4·56			15	5·80	27·54	5·23			10	6·70	20·23	6·73			10	6·3	18·40	7·05		
20	5·3	32·48	5·73			20	5·50	30·10	5·21			15	6·00	24·98	6·38			15	5·80	19·49	5·67		
30	5·2	33·04	4·84			30	5·35	31·27	5·74			20	—	30·26	5·69			20	5·45	23·84	6·43		
40	5·2	33·31	5·70			40	5·30	31·38	4·67			35	5·20	30·62	5·97			28	5·40	24·11	5·74		
50	5·2	33·30	4·47																				

Part of these determinations of oxygen are, unfortunately, encumbered with an error which is owing to an awkward construction of the drawing-off stopcock of the water-bottle, as some air might sometimes enter through it and bubble up through the water-sample. But I do not think that this error can amount to more than a few percent even for the most unsaturated water-samples. And so I have stated all the results. Especially the results from February 1904 are encumbered with this error.

The determinations of oxygen only took very short time onboard. The length of time of the stations was increased with a few minutes for every determination of oxygen which was made. Of course the observer at such a station has more facts to mind than else. But if the weather is not particularly bad the work is not troublesome.

I have further made several determinations of oxygen in surface water from different places. The cause was the strange conditions which were found by the seasonal measurings, that the water in and near the surface might sometimes be strangely far from being saturated. These new determinations, however, all show a standard condition, the water-samples without exception being near the point of saturating for oxygen. It agrees very well with this result that all the watersamples were uncommonly deficient of plancton. The determinations of plancton Mr. Museumsinspektør OSTENFELD was so kind as to make for me, for which I here offer him my best thanks.

Place where the sample was taken	Time for the taking of the sample	Temp. of the surface	Salinity in ‰	Barometer in mm.	Cc. of oxygen in 1 liter: Mean number	Cc. of oxygen in 1 liter: Mean error	Cc. of oxygen in 1 liter: Number of determinations	Plancton	Weather
Samsøbelt. 55°50 N. lat. 10°52'6 E. long.	3/6 1904 5h 30 p. m.	12°7	12·81	764	7·16		1	Insignificant amount (crustacea and peridinea.	Calm and cloudless.
—	3/6 1904 7h 15 p. m.	12°7	12·81	764	7·17		1	—	—
—	3/6 1904 10h p. m.	12°5	13·13	764	7·37	0·045	2	—	—
55°6'4 N. lat. 11°1' E. long.	4/6 1904 12h 15 a. m.	12°7	13·55	764	7·24	0·043	2	—	Cloudless. Wind: NW. Force of wind 1.
Snekkeløbet. 56°52'3 N. lat. 11°15'3 E. long.	4/6 1904 2h 50 a. m.	13°5	15·84	766	7·01	0·037	2	Slight amount (crustacea, peridinea and thin diatomea).	Cloudless. Wind: N. Force of wind 2.
Off Tisvilde. 56°4' N. lat. 12°0' E. long.	4/6 1904 10h a. m.	14°1	13·75	769	6·85	0·034	2	—	Cloudless. Wind: NW. Force of wind 3.
The harbour of Copenhagen off the mole of the free port	5/6 1904 6h p. m.	14°1	10·52	—	7·718	0·027	12	Insignificant amount (animals; many impurities).	Half clouded. Wind: NW. Force of wind 3.

Accuracy of the Method.

The errors, which are entered in the determination of oxygen in seawater described here arise partly from the very method of analysis, partly from the taking of samples, and finally there is a possibility for the introducing of errors on account of the long keeping.

In order to examine the errors which are committed through the method of analysis, L. W. WINKLER determined how much the analysis of samples which were equal as far as possible varied both when

they were made uniformly, and when the circumstances of the making were altered and by this the possible errors.

WINKLER used bottles of about 250 cc. and added 1 cc. lye of soda, 1 cc. solution of manganous chloride, and 3 cc. hydrochloric acid. In 12 different analyses of water, which was saturated with atmospherical air at 16·9° C. and 760 mm., he got the following values for the amount of oxygen which, as constantly in the following, are indicated in dry oxygen, reduced to 0° C. and 760 mm, in 1 liter of water:

6·857	6·849	6·851	6·858
6·846	6·840	6·834	6·844
6·840	6·829	6·813	6·813

Mean number: 6·840; mean error: 0·015.

So the method by repetitions of the analysis gives the same value for the amount of oxygen. In order to prove that this constant value was really the amount of oxygen, WINKLER made 5 analyses of oxygen of water, which was saturated with atmospherical air at 23·64° C. and 760 mm., in which he varied the added quantities of reagents within wide bounds. (He does not state more minutely how). He got the following results:

6·033 5·998 5·983 5·975 5·962. Mean number: 5·990; mean error: 0·027.

The numbers are independent of the added quantities of reagents.

He further made some exact determinations on the amount of oxygen in water, which had been saturated with atmospherical air at 24·24° C. and 760 mm., by a particularly careful boiling off the gases By this he got the following values for the amount of oxygen:

5·933 5·933 5·895 5·845. Mean number: 5·901.

By an extrapolation to the dissolvability of oxygen at 24°24 C. according to WINKLER's determinations of the dissolvability of oxygen at 16·9° and 23·64° C., we get 5·915 cc. in 1 liter. This value answers so completely to the one found by boiling off the gases as may be demanded according to the exactness of the experiments, and shows that WINKLER's titration result is not encumbered with any greater systematical error.

Among some experiments I have made myself the following may be mentioned. In analyses of samples of the drinking water of Copenhagen, taken at the same time, the following amounts of oxygen were found, when the former given method was attended to:

8·025 8·022 8·028 8·013. Mean number: 8·022; mean error: 0·007.

and when the double quantity of reagents were added everywhere:

7·986 8·014 8·067 8·035. Mean number: 8·025; mean error: 0·034.

From these experiments may be concluded that the constant error which is committed by supposing that the soda-lye and the solution of manganous chloride contains as much oxygen as the water which is to be examined, is without any significance for water with an amount of oxygen of about 8.

When we suppose that this is correct, the systematical error, which arises from the contents of oxygen in the reagents, will be about $\frac{8-a}{100}$, if the water contains not 8 but a cc. of oxygen in the liter. To correct for this error will not be of any great aid to the correctness of the result, partly because the result is encumbered with a accidental error, and partly and especially because the value of the correction is not very accurate.

WINKLER has given his method a form which is more accurate but also more troublesome. If we want more accurate determinations of oxygen we may use it[1]). But besides the greater trouble which

[1]) Berichte der deutschen chem. Gesell. 22, pag. 1724.

the analysis occasions, the sampletaking, especially, must also be undertaken far more carefully, and the quantity of water which the water-bottle takes up must be much larger.

That the error which is due to the keeping of the sample until we get ashore is not considerable, is proved by the experiments which I have made, and which have been mentioned above in this paper. According to these experiments it may be supposed that the error arising from the keeping may easily be kept essentially less than 1%, especially when the keeping does not last longer than necessary. In my first experiment it certainly looks as if the amount of oxygen had decreased 1 % in the course of a fortnight. But this apparent decrease is rather caused by inaccuracies in the analyses.

An essential source of errors in the analysis is, no doubt, the taking of samples. When the water has just been saturated with oxygen, and we take care of its not being warmed up until we add the reagents and thus prevent the forming of air bubbles, this source of errors will disappear, but the more we deviate from these conditions, the greater it will become.

In order to get an idea of the conditions in filling bottles with water, which is not saturated, I have made a few experiments.

Three bottles of 250 cc. were connected by means of doubly perforated indiarubber stoppers and glass tubes, which were 4 mm. in diameter inside so that the glass tube from the top of No. 1 was carried down to the bottom of No. 2 etc. Then a current of about 5 cc. a second of boiled water was led through, so that all the bottles were filled, while, however, nothing ran out. By an analysis of the amount of oxygen in these three bottles were found:

in No. 1: 2·271 cc. of oxygen in the liter,
in No. 2: 2·334 - - — - - —
in No. 3: 2·486 - - — - - —

By another experiment, in which the current was stopped when about 100 cc. had run out of the last bottle, were found:

in No. 1: 2·982 cc. of oxygen in the liter,
in No. 2: 3·007 - - — - - —
in No. 3: 3·098 - - — - - —

From this may be seen that water, which is not saturated with air, by being poured into a bottle through a tube which reaches down to the bottom, will absorb rather much oxygen. From the first experiment follows that water with 2·3 cc. of oxygen in the liter by 3 times running through this process will absorb at least $0{\cdot}215 + 0{\cdot}063 =$ about 0·3 cc. af oxygen per liter, consequently 0·1 cc. per liter per time (that is to say when we suppose that the determination of oxygen in bottle No. 1 gives the real amount of oxygen in the water). The water which is found in bottle No. 2 has acquired 0·06 cc. more oxygen by twice displacing water containing more oxygen, first water with about 0·1 cc. more oxygen per liter, and then water with about 0·2 cc. more oxygen per liter. From this we may conclude that water by once displacing water with 0·1 cc. more oxygen will increase its amount of oxygen with about 0·02 cc. per liter, that is with $^1/_5$ of the difference. And from this again we conclude that the water in bottle No. 1 which has had occasion to absorb oxygen by displacing water with 0·2 cc. more oxygen, contains about 0·004 cc. oxygen more per liter than the original amount, and is consequently so near the original amount as needed.

In the second experiment in which about 100 cc. of water had run out of the last bottle, and where the water previously contained more oxygen, the difference between the amounts of oxygen in the bottles has become less and, as may well be imagined, in a ratio which is reasonable when we consider the mentioned circumstances. To saturate the water with atmospherical air at the temperature in which these experiments were made, would require about 6·5 cc. of oxygen.

In the method which was used for the taking of samples only 150 cc. were suffered to run through the bottle, which held 150 cc. itself. More could not be afforded as the water-bottle only held 500 cc., and it would not do to use the water, which inside the water-bottle had been in communication with the atmosphere, and which had, indeed, to be used as water-sample for the determination of chlorine. A sort of water which contains a cc. of oxygen, and which demands b cc. of oxygen per liter to be saturated, will probably in such a taking of sample absorb about $\frac{b \div a}{200}$ cc. of oxygen per liter. The absorption of oxygen may, namely, with rude approximation be supposed to be equal to a constant, k, multiplied with $b \div a$, and according to the experiment as to the filling of the bottles, described p. 11 we get:

$$k \cdot (6{\cdot}5 \div 2{\cdot}3) = 0{\cdot}02$$

$$k = \frac{1}{200}$$

This proceeding in taking the samples can only be used for sorts of water which want less than 4 cc. in being saturated, and for determinations where we do not demand more than an exactness of 1%. For when 4 cc. of oxygen are wanted in order to saturate the water, the error will be about 0·02 and as this gives only an idea of the order of the value, the errors, even if they were corrected with it, would easily be = 0·02.

From these general views and scattered experiments we may judge somewhat as to the correctness of the results which have been acquired by the easy proceedings described here in order to determine the amount of oxygen in seawater.

First, from the analyses which are scattered about in this paper and which are repetitions of each other, we may conclude that the accidental errors with which repeated analyses gather round their average value have a mean error of about 0·04.

The mean errors found and the number of analyses on the base of which each of them is calculated, are namely the following:

Mean error (λ)	Number of the analyses (n)
0·070	4
0·064	3
0·026	6
0.036	2
0·027	4
0·007	2
0·007	2
0·042	2
0·045	2
0·043	2
0·037	2
0·034	2
0·008	4
0·034	4

From this is calculated $\sqrt{\frac{\Sigma \lambda^2 (n \div 1)}{\Sigma (n \div 1)}} = 0{\cdot}040$.

The mean value around which repeated determinations of oxygen will gather with these mean errors will be almost quite correct for water which is very near being saturated with oxygen. But for not saturated and supersaturated water this mean value will be the more different from the real value the more the water deviates from being saturated; the systematical error of the determination will increase together with the water's withdrawing from being saturated.

Setting aside the little error which may possibly be introduced by the keeping, the systematical error may rudely be estimated at:

$$\frac{b \div a}{200} + \frac{8 \div a}{100},$$

where a is the amount of oxygen of the analysis and b the amount of oxygen it ought to contain if it was saturated. The first term is the error which arises from the sampletaking, the second term is due to the amount of oxygen of the reagents. The greatest value of this expression will be about 0·05 when we suppose that the water at most is deviating 50 % from being saturated and that its temperature is between 0° and 20° C. It is not of much use to try to correct for this deviation; for the deviation is too changeable for each case according to the peculiar circumstances of it. It is only the order of amount of the errors which has been estimated in the mentioned value.

On the whole it appears from the above mentioned that generally we may always rely on the first decimal in our results (given in cc. of oxygen per liter of sea-water).

And this exactness will be perfectly sufficient in many researches.